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Monthly Report

July 1987 Number 227

Ten New Reactors Have Entered Service This Year 13

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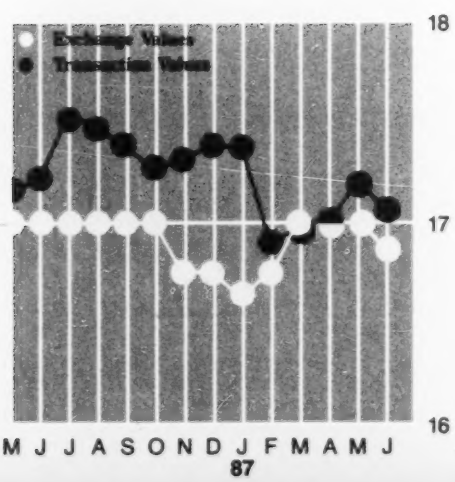

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EXECUTIVE SUMMARY
REPORT 227
(All data as of June 30, 1987)

Exchange Value $16.90, down $0.10

The **Exchange Value** is **$16.90** per pound U_3O_8, down $0.10 since last month.

UF_6 Value $47.75, unchanged

The **UF_6 Value** is **$47.75** per kilogram U as UF_6, unchanged since last month.

Transactions

Twelve recent natural uranium sales are reported, involving **3.9 million** pounds equivalent U_3O_8. Eight of the sales involved spot or near-term delivery, and met the conditions for inclusion in the Transaction Value.

Supply-Demand Ratio Increased to 3.7:1

Active spot and near-term **uranium supply** amounts to **3.7 million** pounds U_3O_8 equivalent, down 400 thousand pounds since last month. Active spot and near-term **uranium demand** totals **1.0 million** pounds, down 375 thousand pounds from last month. The spot and near-term **supply-demand ratio** increased to **3.7 to 1**.

Transaction Value $17.10, down $0.10

The **Transaction Value** is **$17.10** per pound U_3O_8, **down $0.10** since last month. The calculation includes 13 transactions involving a total of 3.5 million pounds U_3O_8 and equivalent UF_6, and covers a period of 3 months.

Loan Rate unchanged at 3%

The **Loan Rate** is **3 percent** per annum, unchanged.

Conversion Value $1.80, unchanged

The **Conversion Value** is **$1.80** per pound U as UF_6, unchanged since last month. Active secondary market supply for conversion services for delivery within three years totals 300 thousand pounds U as UF_6. No active demand is listed this month. Two secondary market conversion transactions are reported.

SWU Value for delivery within one year: $73, down $2.00

The **SWU Value** at .3 tails and for delivery within one year is **$73** per SWU, down $2.00 since last month. No secondary market SWU transactions are reported.

* * *

Recent Developments

So far this year, ten new reactors have entered commercial operation — four in France, three in the USA, and one each in the Federal Republic of Germany, Japan, and South Korea, totaling almost 10,000 MWe new capacity.

Analysis and Commentary

Several economic and political issues affect the Canadian uranium industry, including bilateral trade discussions between the US and Canada, and political trends that could result in the election of parties potentially hostile to uranium production. This article looks at those issues, as well as describing the way in which the Canadian government interacts with commercial uranium transactions.

Analysis and Commentary

Enrichment blending is an alternative to upgrading enriched product to achieve desired enrichment levels. As such, it can offer a way to save costs and time when compared to normal upgrading techniques.

Basic Considerations

Decommissioning nuclear plants involves significant radiation hazards, and requires methods different than those involved in the decommissioning of other types of power plants. This second part of a two-part article examines the radiological environment of shutdown nuclear plants, the technology required to dismantle them, and the estimated costs of fully decommissioning large-scale, commercial reactors.

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NUEXCO REPORT 227 FIGURES OF THE MONTH (June 30, 1987)	This Month (Report 227)	Last Month (Report 226)	12 Months Ago (Report 215)
Exchange Value[1]	16.90	17.00	17.00
Transaction Value[1]	17.10	17.20	17.20
UF_6 Value[2]	47.75	47.75	48.25
Loan Rate[3]	3%	3%	4%
Conversion Value[4]	1.80	1.80	1.80
Near-Term Uranium Supply[5]	3.7	4.1	4.1
Near-Term Uranium Demand[6]	1.0	1.4	2.1
Near-Term Supply-Demand Ratio	3.7	3.0	2.0
Recent Uranium Sales:			
Number of Transactions[7]	12	6	4
Quantity of Material[8]	3.9	5.3	0.6
Nuexco SWU Value:[9]			
at 0.3 tails assay and delivery within one year	73	75	78
USDOE SWU Prices:			
USEC	119.00[10]	119.00[10]	125.00[11]
AFC	153.00[12]	153.00[12]	153.00[12]
Requirements	157.00[12]	157.00[12]	157.00[12]
Incentive Price	90.00[13]	90.00[13]	—
Market Value of Enriched UF_6[14,15]:			
2.5 w/o U_{235}	441	450	457
3.0 w/o U_{235}	563	575	585
3.5 w/o U_{235}	691	702	715
4.0 w/o U_{235}	818	831	847

[1]US $ per pound U_3O_8 equivalent.
[2]US $ per kilogram U as UF_6.
[3]Per annum.
[4]US $ per pound U as UF_6.
[5]Active inquiries to sell, for delivery within 12 months after contract signing (millions of pounds U_3O_8).
[6]Active inquiries to purchase, for delivery within 12 months after contract signing (millions of pounds U_3O_8).
[7]Uranium sales only; does not include loans, conversion, or SWU transactions.
[8]Millions of pounds U_3O_8, equivalent.
[9]US $ per SWU.
[10]Effective 10/1/86.
[11]Effective 10/1/85.
[12]Effective 10/1/84.
[13]Effective 10/1/86, for up to 30% of annual requirements.
[14]Calculated using the Nuexco Exchange Value, Conversion Value, and 0.30 percent tails assay. From 4/30/85 to 11/30/85, calculations used the Nuexco SWU Value for DOE origin and delivery by the end of FY86. As of 12/31/85, calculations use the SWU Value for delivery within one year.
[15]US $ per KgU as UF_6, rounded to the nearest $.

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MONTHLY REPORT ON THE NUCLEAR FUEL MARKET

July 1987 No. 227

R. WESLEY MILLER, *EDITOR* CHARLES B. LEWIS, *ASSISTANT EDITOR*

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To Our Readers

We are pleased to announce that Charles H. Peterson will be joining Nuexco, effective August 1, 1987, as President and Chief Executive Officer. Mr. Peterson comes to Nuexco from Cogema, Inc. where he has been the U.S. Vice President. His years of experience in the nuclear power field and his dynamic personality will bring additional strong industry-experienced leadership to Nuexco and permit us to build on our present service capabilities.

Chuck, raised in Pueblo, Colorado, was appointed to the U.S. Naval Academy in 1956 and served in the U.S. Navy for 13 years, primarily as an engineer in the construction and operation of nuclear powered submarines. Subsequently, he earned graduate degrees in Business Administration and Law at Stanford University. Prior to joining Cogema, he had extensive experience in the Nuclear Power and Aerospace Groups of General Electric Company.

At Cogema, Chuck has been actively engaged in entry of Cogema into the U.S. enrichment market and the expansion of the French nuclear industry into the U.S. market for nuclear products and services. As President and Chief Executive Officer, he will have general managerial and supervisory responsibilities for Nuexco activities, including the establishment of policies, as well as participation in overall strategy development for the individual Nuexco divisions and corporations, among which are Nuexco Trading Corporation headed by Earl Hoellen as President and Nuexco Information Services headed by Gene Clark as President.

Oren L. Benton will remain as Chairman of the Board of Directors of Nuexco, devoting his time primarily to overall organizational planning and new business development for Nuexco and its affiliated entities. The continuing growth of Nuexco will allow us to increase the scope of the services we provide to our customers and to provide our traditional services with greater resources and increased flexibility. Enclosed with this month's Report is a brochure describing some of Nuexco's service capabilities.

* * *

In an effort to maintain and improve the high level of service which has always been Nuexco's goal, we encourage you to let us know your views and opinions concerning Nuexco's publication services. We are asking for this input in the form of a questionnaire which will soon be mailed to each subscriber. In addition, we will also be contacting some customers by telephone. We hope that you will take a few moments to answer the survey so that we can continue to meet the needs of our most valued asset — you, the customer.

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NATURAL URANIUM AND SECONDARY MARKET CONVERSION

(All data as of June 30, 1987)

The **Exchange Value** is **$16.90** per pound U_3O_8, down $0.10 since last month. **Active supply** of natural uranium (concentrates and UF_6) for spot or near-term delivery totals **3,680,000** pounds U_3O_8 equivalent, down 400,000 pounds since last month. The corresponding figure for **active demand** is **1,000,000** pounds, down 375,000 pounds. The spot and near-term **supply-demand ratio** increased to **3.7 to 1.**

The *Current Market Data* section of this Report lists twelve natural uranium sales, totaling 3.9 million pounds U_3O_8 equivalent. US-origin uranium is commanding a premium (relative to the Exchange Value) of $0.60 per pound U_3O_8 (down $0.30) in the form of concentrates, and $1.75 per kilogram U (down $0.50) in the form of UF_6.

The **Transaction Value** is **$17.10** per pound U_3O_8, down $0.10 since last month. The calculation extends over a 3-month period and includes 13 transactions involving 3.5 million pounds equivalent U_3O_8.

The **UF_6 Value** is **$47.75** per kilogram U in UF_6, unchanged since last month. Three transactions involving UF_6 are reported, totaling approximately 400,000 pounds equivalent U_3O_8. Demand for UF_6 remains weak, with only one major buyer in the market.

The **Conversion Value** is **$1.80** per pound U as UF_6, unchanged since last month. Active supply of secondary market conversion services for delivery within three years totals 300,000 pounds U as UF_6. No active demand is reported this month. Two secondary market conversion transactions are reported.

The **Loan Rate** is **3 percent** per annum, unchanged.

* * *

The Exchange Value declined $0.10 this month to $16.90 in a fairly active spot and near-term market for natural uranium. Although little actual price movement has occurred in the market recently, transaction evidence accumulated over the past two months indicated a slight downward correction in the Exchange Value. Seven spot concentrate sales are reported, involving approximately 1.5 million pounds U_3O_8. One US utility bought a substantial quantity of non-US-origin material for near-term delivery, while other entities bought smaller amounts, largely as discretionary purchases. Two long-term sales also are reported, totaling approximately 1.9 million pounds U_3O_8, both to European utilities.

The fragmentation that has characterized the uranium market, based on material origin and the related factors that make origin significant, appears to be diminishing. The US Tenth Circuit Court of Appeals has not yet ruled in the US Producers vs. DOE lawsuit, and most US utilities have used the ten months since the appeal was heard to maximize the amount of US-origin material held in inventory. Activity in the swap market is at its lowest point since Judge Carrigan ruled in June 1986 on Counts I, III, IV, and V of the lawsuit (the ruling was stayed pending appeal in September 1987), and recent attempts to make US-origin swaps have found no buyers at any price. Demand for US-origin continues to decline and, with it, the premium (relative to the Exchange Value) for US-origin, now $0.60 (down $0.30) per pound U_3O_8. With much of their natural uranium inventories already converted to US origin, and lacking any imperative from the courts, most US utilities see little or no reason to pay a premium for US-origin. The little demand for US-origin is highly discretionary and those buyers have been able to wait for cheaper US-origin material to become available.

Although five of the transactions reported this month involved US-origin material, the individual quantities involved were not large, and only one of the sales was made to a utility; the others were made to traders or to producers. The majority of US producers still are unwilling to offer US-mine-origin uranium at prices near the Exchange Value plus the US premium, and continue to await a decision by the Appellate Court that could result in higher prices. However, the current lack of demand for US-origin has created a buyers' market.

There still are substantial quantities of southern and central African uranium available to buyers not constrained by origin. As Canadian U_3O_8 has become less available, African uranium has increasingly come to dominate the spot market, and there are indications that buyers, particularly of large quantities, would find very attractive prices.

The UF_6 Value remained unchanged at $47.75. Three transactions involving UF_6 are reported this month, totaling approximately 400,000 pounds U equivalent. The market for UF_6 remains weak, with only two sellers and only one non-discretionary buyer in the market for a substantial quantity of material. The premium (relative to the UF_6 Value) for US-origin UF_6 declined $0.50 to $1.75 per kgU, following the decline of the US premium for U_3O_8.

* * *

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The Loan Value remained unchanged this month, at three percent. No loan transactions are reported. While some loan opportunities exist, most potential transactions are uneconomic because of the security requirements imposed by potential lenders.

* * *

The Conversion Value is unchanged since last month at $1.80. Two conversion transactions are reported, but the secondary market for conversion services remains relatively inactive. Prices for conversion services in Europe continue to be higher than in the USA. Supply of secondary market services has declined slightly since last month, and what little demand does exist is largely discretionary as to timing.

ENRICHED URANIUM AND SWU

The SWU Value declined to $73 per SWU this month. No SWU transactions are reported in the *Current Market Data* section of the Report this month. Again during June, weak demand caused a slight downward price pressure on the secondary SWU market, with only discretionary buyers in the market for SWU. One seller of a large quantity of SWU, part of whose inventory allegedly has been offered by DOE at $75 per SWU, finally entered the market during June. DOE's role in selling this SWU is controversial at best, and the outcome of its efforts to sell on the secondary market will be closely watched by many market participants. Techsnabexport (USSR) SWU continues to sell at prices below $70.

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CURRENT MARKET DATA

June 30, 1987	Market Values	Active Supply[1] (thousands)	Active Demand[1] (thousands)
EXCHANGE VALUE	**$16.90**/lb. U_3O_8	3,680	1,000
UF_6 VALUE	**$47.75**/kgU		
CONVERSION VALUE	**$1.80**/lb. U as UF_6	300	—
SWU VALUE 0.3 tails assay; delivery within one year	**$73**/SWU		
LOAN RATE	**3%**/annum	1,000	—

	$/lb. U_3O_8	Millions of Pounds	Number of Transactions	Number of Months
TRANSACTION VALUE	**17.10**	3.5	13	3

[1]Supply and demand tables in *Current Market Data* section of this Report detail the numbers for each category.

DEFINITIONS

1. The **Exchange Value** is Nuexco's judgment of the price at which transactions for significant quantities of natural uranium concentrates could be concluded as of the date indicated.
2. The **UF_6 Value** is Nuexco's judgment of the price at which spot and near-term transactions for significant quantities of natural uranium hexafluoride could be concluded as of the date indicated.
3. The **Conversion Value** is Nuexco's judgment of the price at which spot and near-term transactions for significant quantities of conversion services could be concluded in the secondary market as of the date indicated.
4. The **SWU Value** represents Nuexco's judgment of the price at which transactions for the sale of significant quantities of SWUs of stated origin for delivery in the specified time period could be concluded as of the date indicated.
5. The **Loan Rate** is Nuexco's judgment of the annual interest rate at which uranium loans could be concluded as of the date indicated.
6. The **Transaction Value** is a weighted average price of recent natural uranium sales transactions. The calculation is based on prices paid in:
   a. Transactions closed within the previous three-month period for which delivery is scheduled within one year of the transaction date;
   b. At least ten transactions;
   c. Transactions involving a sum total of at least 2 million pounds U_3O_8 equivalent.

   The sample time is extended as necessary to include these minima. Other currencies are converted to US dollars using conversion rates in effect on or near the transaction date.

DERIVATIONS AND COMMENTS

1. All Market Values are based on:
   a. Data from recently completed transactions.
   b. Data from pending transactions.
   c. Firm bids to buy or borrow, and firm offers to sell or lend.
   d. Prices purchasers or rates borrowers have expressed a willingness to pay, but for which Nuexco is not aware of firm bids to buy or borrow, and prices sellers or rates lenders have expressed a willingness to accept, but for which Nuexco is not aware of firm offers to sell or lend.
2. Prices associated with deliveries under old or renegotiated contracts or other than arm's-length transactions are not included in the determination of these Market Values.
3. In the determination of the Conversion Value, Nuexco does not consider transportation charges other than those customarily provided by primary suppliers of conversion services.
4. The prices of conversion services or SWUs delivered under long-term contracts with primary suppliers are not considered in the determination of either the Conversion Value or SWU Value.
5. For the SWU Value, Nuexco converts SWU prices at varying tails and product assays to equivalent SWU prices at a tails assay of 0.30 weight-percent U_{235} and a product assay of 3.0 weight-percent U_{235}, assuming feed costs corresponding to the Nuexco Exchange and Conversion Values determined as of the same date.
6. In calculating the Transaction Value, Nuexco does not account for the price of uranium delivered in connection with contracts which call for "market price" mechanisms. This exclusion applies particularly to contracts in which delivery prices are expressed as a function of future Exchange Values or any other indeterminate variable. Also excluded from the calculation are any other transactions in which the delivery price is defined in such a way that it cannot currently be determined.

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CURRENT MARKET DATA

EXCHANGE VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	per lb. U_3O_8 in Concentrates			per kg. U in Concentrates		
	This Month (June 30, 1987)	Last Month (May 31, 1987)	12 Months Ago (June 30, 1986)	This Month (June 30, 1987)	Last Month (May 31, 1987)	12 Months Ago (June 30, 1986)
Australia (dollar)	23.43	23.84	25.35	60.92	61.97	65.92
Belgium (comm. franc)	640.15	640.30	765.08	1,664	1,665	1,989
Canada (dollar)	22.53	22.84	23.60	58.58	59.37	61.36
EEC (ecu)	14.91	14.90	17.52	38.77	38.75	45.56
Finland (markka)	75.21	74.79	87.13	195.53	194.44	226.53
France (franc)	103.11	102.97	119.30	268.07	267.69	310.15
FRG (mark)	30.90	30.82	37.43	80.34	80.12	97.31
Italy (lira)	22,411	22,269	25,703	58,263	57,894	66,822
Japan (yen)	2,478	2,433	2,810	6,443	6,326	7,305
Netherlands (guilder)	34.82	34.76	42.12	90.53	90.36	109.50
South Africa (rand)	34.53	34.34	42.29	89.76	89.29	109.94
Spain (peseta)	2,415	2,151	2,399	6,278	5,591	6,238
Sweden (krona)	107.92	107.59	121.26	280.56	279.72	317.24
Switzerland (franc)	25.68	25.55	30.63	66.76	66.43	79.62
UK (pound)	10.56	10.43	11.10	27.45	27.11	28.86
US (dollar)	16.90	17.00	17.00	43.94	44.20	44.20

TRANSACTION VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	per lb. U_3O_8 in Concentrates			per kg. U in Concentrates		
	This Month (June 30, 1987)	Last Month (May 31, 1987)	12 Months Ago (June 30, 1986)	This Month (June 30, 1987)	Last Month (May 31, 1987)	12 Months Ago (June 30, 1986)
Australia (dollar)	23.71	24.12	25.65	61.64	67.70	66.69
Belgium (comm. franc)	647.73	647.83	774.08	1,684	1,684	2,012
Canada (dollar)	22.80	23.11	23.88	59.27	60.07	62.08
EEC (ecu)	15.09	15.08	17.73	39.23	39.20	46.10
Finland (markka)	76.10	75.67	88.16	197.85	196.73	229.20
France (franc)	104.33	104.18	120.70	271.24	270.84	313.80
FRG (mark)	31.27	31.18	37.87	81.29	81.07	98.45
Italy (lira)	22,676	22,531	26,005	58,953	58,575	67,608
Japan (yen)	2,508	2,462	2,843	6,519	6,401	7,391
Netherlands (guilder)	35.24	35.17	42.62	91.61	91.43	110.79
South Africa (rand)	34.93	34.75	42.79	90.82	90.34	111.23
Spain (peseta)	2,444	2,176	2,428	6,353	5,657	6,311
Sweden (krona)	109.20	108.86	122.68	283.88	283.01	318.95
Switzerland (franc)	25.98	25.85	30.99	67.55	67.21	80.56
UK (pound)	10.68	10.55	11.23	27.78	27.43	29.20
US (dollar)	17.10	17.20	17.20	44.46	44.72	44.72

[1]Calculated using currency exchange rates published in the *Wall Street Journal* on June 30, 1987.

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CONVERSION VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	per lb. U as UF_6			per kg. U as UF_6		
	This Month (June 30, 1987)	Last Month (May 31, 1987)	12 Months Ago (June 30, 1986)	This Month (June 30, 1987)	Last Month (May 31, 1987)	12 Months Ago (June 30, 1986)
Australia (dollar)	2.50	2.52	2.68	5.50	5.56	5.92
Belgium (comm. franc)	68.18	67.80	81.01	150.31	149.47	178.59
Canada (dollar)	2.40	2.42	2.50	5.29	5.33	5.51
EEC (ecu)	1.59	1.58	1.86	3.50	3.48	4.09
Finland (markka)	8.01	7.92	9.23	17.66	17.46	20.34
France (franc)	10.98	10.90	12.63	24.21	24.04	27.85
FRG (mark)	3.29	3.26	3.96	7.26	7.19	8.74
Italy (lira)	2,387	2,358	2,721	5,262	5,198	6,000
Japan (yen)	263.97	257.66	297.52	581.95	568.04	655.92
Netherlands (guilder)	3.71	3.68	4.46	8.18	8.11	9.83
South Africa (rand)	3.68	3.64	4.48	8.11	8.02	9.87
Spain (peseta)	257.22	227.70	254.06	567.06	502.00	560.10
Sweden (krona)	11.49	11.39	12.84	25.34	25.12	28.30
Switzerland (franc)	2.74	2.71	3.24	6.03	5.96	7.15
UK (pound)	1.12	1.10	1.18	2.48	2.43	2.59
US (dollar)	1.80	1.80	1.80	3.97	3.97	3.97

SWU VALUE AND UF_6 VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	SWU VALUE delivery within one year (June 30, 1987)	UF_6 Value per kg.U in UF_6 This Month (June 30, 1987)	UF_6 Value per kg.U in UF_6 Last Month (May 31, 1987)
Australia (dollar)	101.22	66.20	66.95
Belgium (comm. franc)	2,765	1,809	1,798
Canada (dollar)	97.33	63.66	64.14
EEC (ecu)	64.41	42.13	41.86
Finland (markka)	324.88	212.50	210.07
France (franc)	445.39	291.33	289.21
FRG (mark)	133.48	87.31	86.56
Italy (lira)	96,804	63,321	62,549
Japan (yen)	10,705	7,002	6,835
Netherlands (guilder)	150.42	98.39	97.62
South Africa (rand)	149.13	97.54	96.46
Spain (peseta)	10,432	6,823	6,040
Sweden (krona)	466.16	304.91	302.21
Switzerland (franc)	110.93	72.55	71.77
UK (pound)	45.61	29.83	29.29
US (dollar)	73.00	47.75	47.75

[1]Calculated using currency exchange rates published in the *Wall Street Journal* on June 30, 1987.

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CURRENT MARKET DATA

RECENT TRANSACTIONS[1]

Uranium Sales

Nuexco Transaction Number	Delivery Period	Approximate Quantity (thousands of pounds, U_3O_8 equivalent)	Approximate Price as Percent of Current Exchange or UF_6 Value	Seller	Buyer	Remarks
4061	1987	101-300	101	Trader	Utility	
4067	1987	101-300	100	Producer	Utility	UF_6
4082	1987	50-100	R[5]	R[5]	Utility	UF_6
4085	1987	301-600	100	Producer	Utility	
4086	1988	101-300	109	Producer	Utility	US-origin
4087	1987-90	601-1,000	R[5]	Producer	Utility	
4091	1987	less than 50	106	Producer	Trader	US-origin
4099	1987	50-100	104	Producer	Producer	US-origin
4103	1987	101-300	104	Trader	Producer	US-origin
4104	1987	101-300	98	Producer	Trader	US-origin UF_6
4106	1987	301-600	100	Fabricator	Utility	
4107	1988-93	1,001-1,500	R[5]	Producer	Utility	

[1]Transactions listed are not limited to those in which Nuexco was involved, but also include others of which Nuexco is aware.
[2]If tails assay is unknown or unspecified, Nuexco's calculation of SWU quantity assumes 0.30 w/o tails assay.
[3]Prices are usually normalized to 0.3% tails assay.
[4]Refers to SWU Value that corresponds to SWUs included in transaction. When prices and SWU values are expressed as discounts (e.g., X dollars less than DOE's USEC base price at time of delivery), the percentage refers to the ratio of the *discounts*, not the ratio of the prices.
[5]The notation *R* means that Nuexco either does not know, or that Nuexco has restricted that information to protect client confidentiality.

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Conversion Services
Secondary Market Sales

Nuexco Transaction Number	Delivery Period	Approximate Quantity (thousands of pounds, U equivalent)	Approximate Price as Percent of Current C.V.	Seller	Buyer	Remarks
4095	1987	101-300	less than 103	R[5]	Utility	
4101	1987	101-300	R[5]	Trader	Utility	

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CURRENT MARKET DATA

URANIUM SUPPLY
(June 30, 1987)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U_3O_8) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Available for Sale:			
ACTIVE			
2335*	270	—	
2764*	300	—	
2893A	720	—	UF_6
2989	40	—	
2996	200	500 per year	1988-90
3023	400	500	UF_6
3121	1,000	—	
3238	500	—	
3244	250	300 per year	1988-93
2263	—	400 per year	1989 on
2781	—	400 per year	1988-95
3123	—	2,000	1988
3171	—	200 per year	1988-92
TOTAL:	3,680		
INACTIVE			
2297	100	100 per year	1988-89
2933*	300	300 per year	1988-90
2967	1,000	—	
3168	50	100 per year	1988-92
2625	—	500 per year	1988 on
2981	—	600 per year	1988-91
3128	—	100	1988 on
3230*		500	1988 on-
TOTAL:	1,450		

*New or revised since last month.

[1] Méasured from the date of this Report.

[2] For delivery within one year. This category excludes material deliverable within one year under other than spot or near-term contracts.

Projects removed since last month: 2336, 3166, 3316.

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URANIUM DEMAND
(June 30, 1987)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U_3O_8) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Inquiries to Purchase:			
ACTIVE			
2890	175	—	
2911	65	—	UF_6
3220*	500	—	U_3O_8 or UF_6
3251*	260	—	
2738	—	1,000	1989 on
2936	—	400 per year	1988-95
2962	—	500 per year	1988 on
2985	—	675 per year	1992 on
3120	—	1,000 per year	1988-91
3137	—	4,800 per year	1993-97
3149	—	300	1989
3193	—	700 per year	1989,91,94,96
TOTAL:	1,000		
INACTIVE			
2798	150	—	
2984	260	—	U_3O_8 and UF_6
3149	300	—	1989
3192*	50	—	
3249*	150	—	
TOTAL:	910		

*New or revised since last month.
[1]Measured from the date of this Report.
[2]For delivery within one year. This category excludes material deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 3141, 3175, 3191, 3216.

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CURRENT MARKET DATA

CONVERSION SUPPLY AND DEMAND
(June 30, 1987)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U as UF_6) Within 3 Years	Beyond 3 Years	Remarks
Available for Sale: ACTIVE			
2764B	300	—	
TOTAL:	300		
Available for Sale: INACTIVE			
2859	750	750	
3165	330	—	
TOTAL:	1,080		
Inquiries to Purchase: INACTIVE			
2833	440	—	
TOTAL:	440		

*New or revised since last month.
[1]Measured from the date of this Report.
Projects removed since last month: 2833, 2988, 2997.

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LOAN SUPPLY AND DEMAND
(June 30, 1987)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U_3O_8) Within 1 Year	Beyond 1 Year	Remarks
Available for Loan			
ACTIVE			
2909	1,000	—	
TOTAL:	1,000		
INACTIVE			
1938	2,000	—	UF_6
2036	500	—	
2912	1,000	—	
2920	2,000	—	
TOTAL:	5,500		

*New or revised since last month.
[1]Measured from the date of this Report.
Projects removed since last month: None.

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CURRENT MARKET DATA

SWU SUPPLY AND DEMAND
(June 30, 1987)

Nuexco Project Number	Delivery Period[1] (Thousands of SWUs) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Available for Sale:			
ACTIVE			
2969*	200	—	1988
3173	45	—	1987
3291*	360	—	1987
TOTAL:	605		
INACTIVE			
2571	50	—	1987
3213	150	—	
TOTAL:	205		
Inquiries to Purchase:			
ACTIVE			
2999	50	100	1988
TOTAL:	50		

*New or revised since last month.
[1]Measured from the date of this Report.
[2]For delivery within one year. This category excludes SWUs deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 3159, 3322.

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MID-YEAR REACTOR PROGRAM UPDATE

So far this year, ten reactors, totaling nearly 10,000 MWe capacity, have entered commercial service in five countries. Four new reactors have begun operations in France, adding over 3,400 MWe to the French nuclear capacity, and two others are scheduled to begin operating by the end of this year, adding another 2,600 MWe of new capacity, for a total increase of 6,000 MWe by the end of the year. In the Federal Republic of Germany, Japan and South Korea, single units have gone into operation.

In the USA, three reactors have begun commercial operation and eight others are scheduled to do so by the end of 1987. If all those units do go on line by the end of the year, nearly 11,000 MWe (net) of nuclear capacity will be added to the US nuclear operating base in 1987, somewhat more than the 1985 and 1986 figures of 9,000 and 9,600 MWe, respectively.

Table 1

NUCLEAR UNITS PROGRESS THROUGH JUNE 1987

Unit	Utility	Country	MWe Net	Type	COD
Entered Commercial Operation					
Cattenom 1	Electricite de France	France	1,265	PWR	April 1987
Chinon B3	Electricite de France	France	870	PWR	March 1987
Flamanville 2	Electricite de France	France	1,290	PWR	March 1987
Saint Alban 2	Electricite de France	France	1,300	PWR	March 1987
THTR-300	VEW[1]	FRG	300	THTR	June 1987
Tsuruga 2	JAPC[2]	Japan	1,160	PWR	Feb 1987
KNU-8	KEPCO[3]	Korea	900	PWR	June 1987
Byron 2	Commonwealth Edison	USA	1,120	PWR	April 1987
Shearon Harris	Carolina Power & Light	USA	900	PWR	May 1987
Vogtle 1	Georgia Power	USA	1,100	PWR	May 1987
Undergoing Fuel Loading or Low-Power Testing					
Bruce 8	Ontario Hydro	Canada	750	CANDU	July 1987
Cattenom 2	Electricite de France	France	1,265	PWR	July 1987
Chinon B4	Electricite de France	France	870	PWR	Aug 1987
Beaver Valley 2	Duquesne Light Company	USA	833	PWR	4th/Q 1987
Braidwood 1	Commonwealth Edison	USA	1,120	PWR	Sept 1987
Clinton 1	Illinois Power	USA	933	BWR	April 1987
Fermi 2	Detroit Edison	USA	1,093	BWR	Sept 1987
Nine Mile Point 2	Niagara Mohawk	USA	1,080	BWR	4th/Q 1987
Palo Verde 3	Arizona Public Service	USA	1,221	PWR	Oct 1987
Perry 1	Cleveland Electric Illuminating	USA	1,205	BWR	3rd/Q 1987
South Texas Project 1	Houston Lighting & Power	USA	1,250	PWR	Dec 1987

[1]Vereinigte Electrizitaetswerke Westfalen AG.
[2]Japan Atomic Power Company.
[3]Korea Electric Power Company.

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RECENT DEVELOPMENTS

Canada

Ontario Hydro's Bruce Unit 8, a 750-MWe Candu reactor, currently is undergoing commissioning and testing. The unit is scheduled to be connected to the grid in July or August 1987. Pickering Units 1 and 2, which have been shut down for the past two years for retubing, are scheduled to resume operation in July and December 1987, respectively.

France

Four new units have entered commercial service in France so far in 1987. In March, Saint Alban Unit 2, Flamanville Unit 2 (1,300-MWe PWRs) and Chinon Unit B-3 began operation. The Chinon plant (870-MWe PWR) was first connected to the grid in October 1986, and is the 33rd of the 900-MWe series in France. And in April, Cattenom Unit 1 (1,265-MWe PWR) entered commercial operation.

Two other 1,300-MWe units are scheduled for operation later in 1987. Cattenom Unit 2 began loading fuel at the end of April and is expected to begin service in July. Fuel loading at Belleville Unit 1, scheduled to begin in June, has been postponed because of the unit's failure to pass containment leak tests. The unit was expected to begin commercial operation in August, but is tentatively scheduled to start before the end of the year.

Federal Republic of Germany

The 300-MWe Thorium High-Temperature Reactor (THTR-300), owned by a consortium of utilities and other German companies, has entered commercial operation. The unit generated over one billion kilowatt-hours during testing and trials. RWE's (Rheinisch-Westfaelisches Elektrizitaetswerk AG) Muelheim-Kaerlich 1,227-MWe PWR also has received its operating license. RWE expects to start the unit by the end of July 1987.

Japan

Japan Atomic Power Company's Tsuruga Unit 2 (1,160-MWe PWR) entered commercial operation in February 1987. Construction started on the unit in April 1982. Two other units, Chubu Electric Power Company's Hamaoka Unit 3 (1,100-MWe BWR) and Tokyo Electric Power Company's Fukushima Unit II-4 (1,100-MWe BWR) are scheduled to enter service later in the year, bringing Japan's total nuclear generating capacity to 25,850 MWe.

South Korea

Korea Nuclear Unit 8 (KNU-8), a 900-MWe PWR, entered service in June 1987. With the addition of this unit, Korea's nuclear plants contribute over 30 percent of the country's total rated electrical capacity.

USA

Vogtle Unit 1, Georgia Power Company's 1,100-MWe PWR entered commercial operation May 31. Construction of the Westinghouse unit began in 1974. Total cost of both Units 1 and 2 (Unit 2 is scheduled to begin operation in 1988) is nearly $9 billion.

Carolina Power & Light Company's Shearon Harris Unit 1 (900-MWe Westinghouse PWR) began commercial operation at the beginning of May 1987. The unit received its full power license in January, and first reached full power on April 21. The plant's construction cost $3.8 billion. Three other units originally planned for the site were canceled several years ago.

Commonwealth Edison's Byron Unit 2 (1,120-MWe PWR) entered commercial service on April 11, almost two months ahead of schedule. The company's Braidwood Unit 1 (1,120-MWe Westinghouse PWR) received a full power license in June, and currently is undergoing testing. The utility expects the unit to begin commercial operation in September 1987.

Clinton Unit 1, Illinois Power Company's 933-MWe General Electric BWR, was connected to the power grid on April 24. The utility is currently engaged in power ascension and testing of the unit.

Duquesne Light Company's Beaver Valley Unit 2 is proceeding with fuel loading after receiving its fuel loading license on May 28. Commercial operation is scheduled to begin before the end of 1987.

Palo Verde Unit 3, Arizona Public Service Company's 1,221-MWe Combustion Engineering PWR, received its low-power license in March 1987. Although fuel loading was completed in April, testing and operation awaits completion of diesel generator testing. Barring further complications, the utility expects the unit to enter commercial service by October 1987.

Niagara Mohawk's Nine Mile Point Unit 2 (1,080-MWe BWR) began low-power testing in May. Commercial operation is scheduled to begin by the end of 1987.

Fermi Unit 2, Detroit Edison's 1,093-MWe BWR, is undergoing testing at about half power. The company hopes to begin commercial operation by September 1987.

Advanced testing at Cleveland Electric's Perry Unit 1, a 1,205-MWe BWR, is underway. The unit is scheduled to enter commercial service in the third quarter of 1987.

Houston Lighting and Power Company's South Texas Project Unit 1 (1,250-MWe PWR) began loading fuel in June. The unit is scheduled to enter commercial operation by December 1987.

On April 30, 1987, Public Service Company of Colorado's Fort St. Vrain reactor returned to service, after being shut

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down since May 31, 1986. An NRC order had allowed the plant to restart, but limited power generation to 35 percent pending the NRC's review of safe shutdown analyses. The NRC commissioners now have voted to allow the plant to operate up to 82 percent of the 330-MWe design capacity, and the company plans to begin a gradual power ascension soon.

In other reactor developments, Dairyland Power Cooperative has permanently closed the 55-MWe LaCrosse unit. The LaCrosse reactor had been operating since 1969, and is the sixth commercial reactor to be closed in the USA. The other plants that have been closed are Dresden 1, Fermi 1, Humboldt Bay 3, Indian Point 1, and Peach Bottom 1.

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ANALYSIS AND COMMENTARY

ECONOMIC AND POLITICAL ISSUES AFFECTING THE CANADIAN URANIUM INDUSTRY

Introduction

The worldwide view of Canadian uranium production and supply is primarily based on perceptions of high ore grades, rich reserves, and almost unlimited long-term supply capabilities. Canada's status as the world's leading uranium-producing nation reinforces this view; in 1986, Canada produced more uranium concentrates than the next two largest producing countries combined. While this view is accurate, Canada's complex economic and political forces sometimes override otherwise rational production decisions. An understanding of those factors and their implications for a uranium producer is essential to a full understanding of Canada's supply position. For example:

1. Canada's current weak economic performance might tempt federal or provincial governments to impose added taxes or royalties. Canadian producers might respond by raising prices to maintain profit margins or by increasing production to maintain net profits, or some combination of the two. In any case, some government sales assistance, such as relaxing the rules on upgrading U_3O_8 to UF_6, would be needed to enhance Canadian producers' competitive positions enough to support the added burden imposed by government action.

2. Significant shifts in political party balances have taken place, both at the national and provincial level, and those shifts could have far-reaching effects on the uranium production sector. In particular, a victory in the next provincial elections in Saskatchewan by the New Democratic Party (NDP), which is opposed to uranium mining, might greatly hinder the expansion of production in that province, and could even curtail existing production.

The Canadian Economy

Similarities between Canada and the USA often invite comparisons of the two nations, especially because of proximity, trade patterns, alliances, and similarities of language and culture. Although these comparisons can be misleading, they are often the best indicators of relative performance. The relationship of the Canadian dollar to the US dollar is one indicator of Canada's relative economic performance. For many years, the Canadian dollar maintained a rough parity with the US dollar, but since about 1960 it has gradually weakened relative to US currency. Interest rates generally are higher in Canada than in the USA, and although this differential has widened over the past ten years, it has had little strengthening effect on the Canadian dollar.

Canadian per capita Gross National Product (GNP) has declined since 1976, and currently is approximately 85 percent that of the USA. Although per capita debt in Canada historically had been lower than in the USA, the positions have been reversed since 1979 and Canadians on average now carry 13 percent more debt than Americans. In addition, consumer prices have failed to stabilize. In the first quarter of 1987, consumer price inflation in Canada was higher than in any other industrialized country. The decline in disposable incomes which has occurred since the mid-1970s has been aggravated by an unemployment rate of 9.3 percent, a major political concern.

The disappointing economic state of the country, even after three years of solid economic recovery elsewhere in the industrialized world, combined with several unpopular tax increases, has caused a steady decline in popularity of the ruling Progressive Conservative Party (PCP). For the first time since its inception in 1961, the New Democratic Party (NDP) has achieved first place in national polls. The possibility of a two-way contest in the next federal election between the NDP and the Liberal Party (formerly led by Pierre Trudeau) could leave the pro-uranium Progressive Conservative Party completely out of the running.

The Saskatchewan Economy

Mining and agriculture account for 25 percent of the gross domestic product in Saskatchewan. Farm income has suffered with the worldwide oversupply of grain, although federal government equalization payments have averted a potential crisis. Mineral revenues, however, have been greatly reduced by the fall in international oil prices. In response to a provincial deficit which has grown to about C$1.2 billion, the Saskatchewan government is attempting to cut $800 million, or about 20 percent, from total spending.

Despite the 1986 increase of 2.5 million pounds U_3O_8 in the province's uranium production, uranium revenues also have leveled off due to contract renegotiations and a greater proportion of market-price contracts (Figure 1). Altogether, Saskatchewan's depressed mineral resource sector is expected to keep the province's economic growth below the national average and, for the first time in many years, Saskatchewan's economic performance may fall below that of the chronically-depressed Atlantic provinces.

The position of the Progressive Conservative Party in Saskatchewan also has eroded. The 1986 election left the party with a majority (Table 2), but the provincial NDP received nearly half the popular vote. In addition, the PCP lost heavily in urban areas. While development of the Cigar Lake mine has the support of the current PCP administration,

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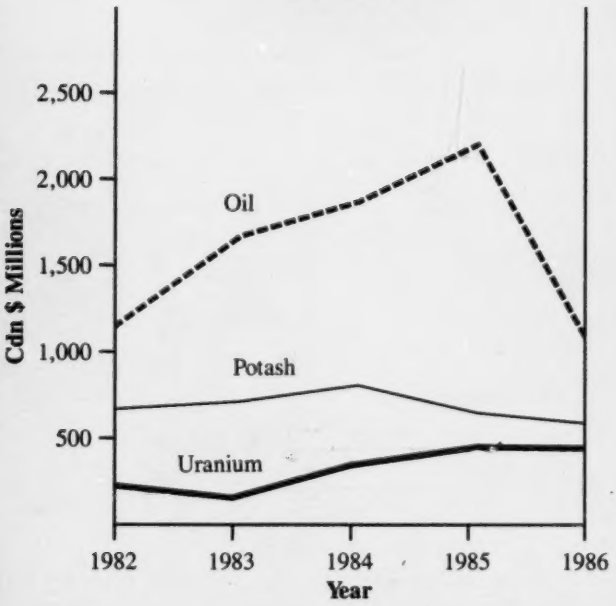
Figure 1

SASKATCHEWAN MINERAL PRODUCTION 1982-1986



a return to power by the NDP in the next election, to be held in 1989 or 1990, could threaten the future of uranium mining in the province.

The NDP's opposition to uranium production is supposedly based on its objection to uranium's military applications, including sales of uranium to nuclear weapons states and certain other countries, rather than on environmental concerns that have sometimes caused opposition elsewhere. The NDP has announced its intention to halt uranium mining altogether at some unspecified future date, even though party spokesmen have mentioned few details of how the threat might be carried out.

Table 2

SASKATCHEWAN PROVINCIAL PARTY STANDINGS BEFORE AND AFTER THE 1986 ELECTION

Party	Before	After
Progressive Conservative	52	38
New Democratic Party	9	25
Liberal	0	1
Total Seats:	61	64

US-Canada Bilateral Trade

US trade with Canada totaled US$125 billion in 1986; each nation is the other's largest trading partner. Approximately 30 percent of that trade is subject to tariffs. Trade negotiations have been underway for over a year, and the two countries hope to have a free-trade agreement in place by early October. An omnibus agreement would be aimed at eliminating many of those protectionist measures, with the ultimate goal of strengthening the economies of both nations.

Both the Mulroney and Reagan Administrations appear strongly in favor of liberalizing trade. Reagan has long supported free trade in international commerce, and unless the USA can maintain free trade with its largest trading partner, economic accommodation with other US trading partners will be very difficult to achieve. The issue has even greater significance for Mulroney, whose political future could depend on the favorable outcome of the negotiations. The US trade issue is perhaps his most significant foreign policy initiative, and any changes could affect the Canadian economy and unemployment rate. The US market is one of the primary factors affecting the health of the Canadian economy, accounting for more than two million jobs. Access to the US market is not as secure as many in Canada would prefer, and it threatens to become less so. The Canadian government estimates that if the USA were to impose across-the-board trade restrictions as a means of reducing the US trade deficit, the effect on Canadian employment would be dramatic — a ten percent reduction in exports could eliminate 250,000 Canadian jobs.

However, both leaders will face strong opposition to the removal of trade barriers, especially from groups such as the Canadian auto industry and the US lumber industry. Indeed, many Canadians oppose the government's free-trade initiatives. Results of a poll conducted late in 1986 showed a considerable range of opinion on the question of the effects of free trade: 46 percent of Canadians felt free trade with the USA would mean a stronger Canadian economy, but 36 percent disagreed. On the other hand, 43 percent thought that free trade would result in higher unemployment in Canada while 38 percent disagreed. The poll also showed that overall support for free trade has declined steadily, from 58 percent in November 1985 and 78 percent in April 1984.

Beyond responding to nonproliferation concerns, the Canadian government also oversees a number of commercial aspects of the industry. These include review of export contracts, requiring the upgrading of Canadian U_3O_8 in most circumstances, setting guidelines for prices and foreign investment in the mining industry, and maintaining security of supply for the domestic nuclear power program. While

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many of those practices have been in place since the beginnings of the Canadian uranium industry, all of them appear susceptible to elimination out of economic or political necessity. The remainder of this article examines each of these topics in greater depth.

Canadian Government and Uranium — The Export Review Process

Government review of uranium contracts, initiated in 1969, still is required prior to the filing of an application to the Atomic Energy Control Board (AECB) for an export permit. The original policy statement on contract review was made in 1969 by the Minister of Energy, Mines and Resources:

> "To protect the national interest in the different circumstances which now face us we will henceforth require that all contracts covering the export of uranium or thorium be examined and approved by the appropriate federal agency before any application for an export permit is considered. The examination will cover all aspects and implications of the contract such as nuclear safeguards, the relationship between the contracting parties, reserves, rate of exploitation, domestic requirements, domestic processing facilities, and selling and pricing policy. Approval will not normally be given to contracts of more than ten years duration unless provision is made for renegotiation of price."

In this statement, the Canadian government demonstrated its intention to use the provisions of the Atomic Energy Control Act to exert control over such aspects of commercial uranium marketing as prices and selling policy, which had not previously received overt attention. Government intervention had first begun four years earlier when the Canadian government, by imposing new safeguards conditions, effectively blocked a large uranium sale to France by Denison Mines Ltd., at a price the government considered to be too low. The "appropriate federal agency" became two agencies — the Atomic Energy Control Board and the Department of Industry, Trade and Commerce. In 1983, the Minister of Energy, Mines and Resources made the latest statement on the review process:

> "The review will continue to ensure that contracts are in the national interest. The terms of sale should equitably balance benefits and risks and should generally be in accord with those being obtained by Canadian and international producers for uranium under contracts of similar duration. The review will continue to take into account the implications of such matters as international non-proliferation, the relationship between contracting parties, price and volume of sales to the export market and reserves and rate of exploitation."
>
> Hon. Jean Chretien
> September 15, 1983

The contract review is performed by the Uranium Export Review Panel (UERP), which now includes representatives of the departments of Energy, Mines and Resources (EM&R) and External Affairs, as well as the aforementioned entities. Until recently, three ministers' signatures were required for each approval. Now, however, if the contract requires no exemptions to the policy guidelines, UERP can approve it directly. Contracts requiring exemptions can take 2-4 months for approval, versus 2 to 4 weeks for those not requiring exemptions.

Canada's Upgrading Policy

The Canadian government has required that unless a specific exemption is granted, uranium must be upgraded "to the greatest extent possible" in Canada prior to export, providing the Eldorado Nuclear UF_6 conversion plant has the capacity and is generally competitive with other converters. The policy was reaffirmed in a September 1983 letter to producers which also added the emphasis that "exemption will only be given in highly exceptional circumstances." The compulsory upgrade policy has become more controversial lately for a number of reasons:

1. The Saskatchewan producers cannot sell their entire production as UF_6 because many buyers are already committed to conversion contracts. The existence of the policy and the difficulty and time involved in obtaining exemption often deter buyers.

2. On the basis of the government's continuation of this policy, Eldorado Nuclear has invested heavily in doubling capacity of the Port Hope conversion facility, which is the primary cause of the company's large debt burden. That debt is probably the chief factor in the difficulties surrounding the attempted privatization of the company.

3. The forced conversion concept is often viewed as an irritant in bilateral trade negotiations with the USA, particularly as Canadian producers already are under pressure from pending US legislation and judicial proceedings that could enforce limitations on uranium imported into the USA or tariffs on imported UF_6.

The Minister of Energy, Mines and Resources made the latest official statement on upgrading in October 1985:

"Ministers now reaffirm the policy that uranium be

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refined and converted in Canada before export, provided that Eldorado is generally competitive. This condition applies to competition with other primary converters and not with sales from inventory (the secondary conversion market).

Ministers will permit a limited degree of flexibility for new sales by Canadian producers in the difficult market that is expected to prevail in the near term. 'Exceptional circumstances' now are defined as follows:

1. Exemptions to further processing of Canadian-origin uranium in Canada before export will be granted for those situations where an end user has existing bona fide arms-length conversion contracts, the early termination of which would not be possible without significant financial hardship.

2. Conversion contracts must have been in place on or before December 31, 1980 and must cover the delivery period for which an exemption is requested. Options to extend the conversion contracts would not be considered as grounds for such exemptions, nor would open-ended contracts to cover ongoing conversion requirements. Canadian producers will be required to assist in clarifying the status of end-user conversion contracts, and in satisfying federal officials that uranium sales contracts meet the requirements for exemption as defined above."

According to a report by The Canadian Press, between 1979 and 1983 the Canadian government granted 16 exemptions, covering about 27 percent of total uranium shipments. In the future, however, this is expected to decrease to about 10 percent, as Key Lake producers commit their output. It is conceivable that Eldorado could operate profitably without the upgrading policy, provided that its conversion prices are competitive and are unhindered by currency exchange rates. In any event, as US utilities' contracts with domestic converters expire, the justifications for exceptions will no longer apply, and Canadian producers will encounter commercial problems unless Canadian UF_6 is as competitive internationally as Canadian U_3O_8. Ultimately, the upgrading policy could become a negotiated concession in the US-Canada bilateral trade talks. (A recent report of those discussions indicated that the upgrading policy could be changed at some point in the future.)

However, because of the ongoing litigation between US uranium producers and the US DOE, and because of various Congressional attempts to limit the use of non-US uranium by US utilities, there remains a serious potential threat to Canadian exports of uranium to the USA. At present, the litigation languishes unresolved in the Tenth Circuit Court of Appeals, but the anticipated favorable ruling for the US producers would probably place restrictions on the amount of non-US uranium that US utilities could enrich under their DOE contracts. Legislative attempts to achieve similar ends, such as Senator Pete Domenici's (R, New Mexico) bill restricting the use of non-US uranium to 50 percent of requirements, have not yet succeeded. Nevertheless, Canadian producers stand to suffer the greatest losses if such a law is passed, especially if a total or near-total embargo is enacted. Thus, those attempts to enact severe limitations on the market for Canadian uranium will likely discourage the Canadian government from eliminating or easing the upgrading policy until such threats are reduced or eliminated.

Government Pricing Policy

In 1977 the Minister of Energy, Mines and Resources formulated the government's pricing policy:

> "In the past few years, the rapid price rise which has occurred for uranium and the differing terms of many contracts have resulted in applications for annual export permits containing widely varying prices. In some cases, export approval for old contracts was sought at prices considerably lower than the Board was willing to approve for new sales. In some others, the cost of mining the uranium had overtaken the price. In these cases, or where costs have increased to an extent that selling prices are too low to provide a reasonable return, the Canadian producers are being encouraged to renegotiate their contracts..."
>
> "With regard to all contracts not yet approved by the Atomic Energy Control Board, and all future contracts, the government will expect that terms of sale will provide for an annual renegotiation of price based on then existing world prices giving consideration to such factors as term and size of contract and any special financing arrangements. Provision should also be made for an escalating floor price which will protect investment in production facilities."

Within a few years after this statement was made, the worldwide decline in uranium prices forced the UERP to adopt a more pragmatic view in interpreting the 1977 policy, and the tendency toward market-related prices soon became common. The original philosophy was softened somewhat by the Uranium Resource Appraisal Group in their annual report:

> "All uranium export contracts are required to contain floor prices or similar mechanisms, which protect investment and employment in the uranium production facilities, and pricing terms that provide for an equitable

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balance of benefits and risks and that are in general agreement with those being obtained by Canadian and international producers of uranium under contracts of similar duration."

As a result, numerous recent contracts contain so-called "soft" or "walkaway" floor prices, which are provisions that release the buyer from obligation to purchase if the floor price mechanism acts to his detriment. Exactly how an "equitable balance of benefits and risks" is determined is unclear, but insofar as investment and employment can be protected by selling at prices which barely cover variable costs, heavily discounted sales can be approved. It appears that pricing policy now relates more to direct operating cost than any other single consideration.

Foreign Investment in Uranium

Voter attitudes toward foreign investment in the energy business appear to have changed little during Prime Minister Brian Mulroney's Conservative administration. According to a national poll conducted in April 1987, 77 percent of those polled felt that the federal government in Ottawa should act to prevent the private takeover of Canadian-owned oil and gas companies. The present controversy over the US-based Amoco Oil Corporation's takeover attempt of Canada's largest oil company, Dome Petroleum, is similar to the reaction of the uranium industry to a situation that involved the pending sale of Denison Mines in 1970. That event brought about the current laws pertaining to foreign ownership of Canadian uranium deposits, as implied in the remarks by former Prime Minister Trudeau in March 1970:

> "Last week the government of Canada learned that a substantial ownership interest in Canada's largest uranium mining company might be passed into non-Canadian hands. The government cannot delay making its position clear because it is understood the transaction may be close to completion..."
>
> "...Our reservations about this change of control of Canadian uranium resources are such that if necessary the government will introduce an amendment to the Atomic Energy Control Act, to take effect as of today, to prevent such a transaction."

Since that time, the Canadian government has limited non-Canadian ownership of uranium properties at the production stage to 33 percent. A June 1978 amendment allowed non-Canadian ownership to increase to 50 percent in cases where the property was Canadian-controlled or where development of the property was determined to be "of significant benefit to Canada." In January 1984, the government extended the date for meeting Canadian ownership requirements for up to three years after commencement of production, under the following conditions:

1. The partners in a joint venture in which non-resident participation exceeds 50 percent continue to seek, and report regularly to officials of the Department of Energy, Mines and Resources on efforts to find, sufficient Canadian equity participation to meet the policy requirements prior to commencement of production;
2. The partners in the joint venture negotiate with the Canadian government a mutually agreeable and definitive agreement specifying actions to ensure that the mining project meets the Canadian ownership criteria within three years after commencement of production;
3. A determination is made by the Canadian government that the proposed project, if not Canadian-controlled, will be of significant benefit to Canada.

No further policy statement with respect to foreign ownership of uranium mining has been made since the Mulroney government took office in late 1984. The phrase "of significant benefit to Canadians" has been replaced by "of net benefit to Canadians" in the June 1985 Investment Canada Act, which replaced the Foreign Investment Review Act. To date, the policy on foreign investment in uranium production has not been tested, and reviews under the Investment Canada Act have not halted even one foreign acquisition or new business investment. Figure 2 shows the percentage of investments, by country, made under the Investment Canada Act. This type of flexibility is a change from the past and is not likely to continue if a Liberal or NDP administration is elected, especially if its "opposition" party in Parliament also has a similar political philosophy regarding foreign investment.

Uranium for Domestic Use

In 1974, a rapid increase in inquiries for long-term supply commitments and projections of a four- to sixfold increase in annual demand for uranium "within the next decade" led the Canadian government to conclude that it should regulate forward coverage in reserves and in milling capacity. This action was deemed necessary to protect Canada's domestic uranium consumers, according to the September 1974 statement by the Minister of Energy, Mines and Resources:

> "Sufficient uranium must be reserved for domestic use to enable each nuclear power reactor operation, committed for construction or planned for operation ten years into the future, to operate at an average annual capacity factor of 80 percent for 30 years from the start of the

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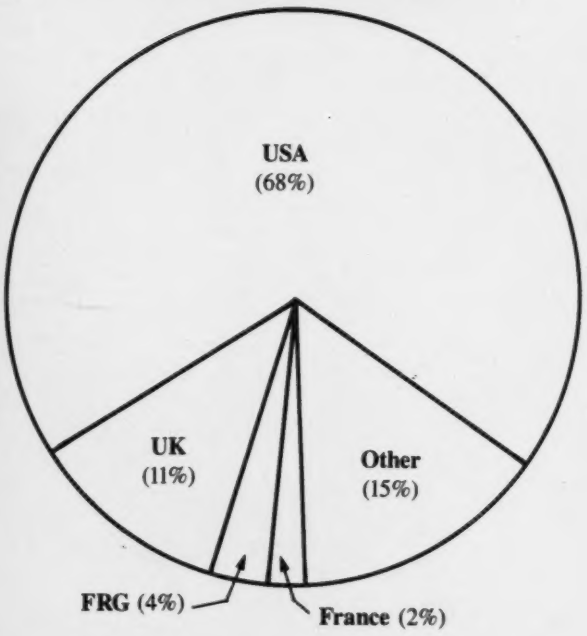
Figure 2

1986 FOREIGN ACQUISITIONS UNDER THE INVESTMENT CANADA ACT (TOTAL: 475 ACQUISITIONS)



period, or in the case of reactors which are not in operation, for 30 years from their in-service dates."

The report further stated that utilities were required to demonstrate forward supply contracts sufficient to enable each operating reactor to be operated at an annual capacity factor of 80 percent for at least 15 years, or for reactors committed but not yet operating, for 15 years from their in-service dates. However, the government would encourage commitments to be made for periods of more than 15 years. Previously, the Canadian exporters' contracts were reviewed for safequards implications, the relationship between contracting parties, price and volumes of sales, and reserves and rate of exploitation. Under the new policy, consideration would then also be given to "the adequacy of the contracting company's uncommitted uranium reserves to meet its share of the Canadian domestic reserve margin." Export contract approvals were limited to a maximum of 10 years from the date of signing, with contingent approval possible for an additional 5 years. Domestic utilities could, however, recall part of this contingent tonnage through the AECB.

With the reduction in growth projections for the Canadian nuclear power program, and increases in domestic reserves, the Minister of Energy, Mines and Resources in September 1983 relaxed this policy. Henceforth, the Canadian nuclear program's security of uranium supply would be monitored by examining available supply and contracted commitments on a national basis, rather than examining the situation for each individual producer or utility. In addition, export contracts would be approved for up to 15 years and, in the case of contracts associated with the sale of a CANDU reactor "and where benefit to Canada from such CANDU sale is significant," approval would be given for up to 30 years supply for the unit.

Conclusion

Canada's relatively weak economic performance in recent years could affect the Canadian uranium industry by creating a need to enhance the commercial positions of Canadian producers, and by fostering even greater production among the country's raw materials sector, including uranium. However, potential changes in political structure, both on national and provincial levels, could also have a negative effect on Canada's uranium industry. Additional gains by the generally anti-uranium NDP in the province of Saskatchewan could threaten the future outlook for both for existing operations as well as Cigar Lake and other promising orebodies.

The potential for legislation or regulations in the USA designed to protect its uranium industry presents especially difficult problems for those Canadian producers that rely on sales to US utilities. Trade tensions between the USA and Canada recently have led to Canadian initiatives that support a free-trade situation between the two countries. However, special interest groups on both sides of the border may inhibit these attempts. For the Canadian uranium industry, whose market in the USA represents 20 percent of Canada's annual uranium production, potential restrictions on imports into the USA could seriously damage Canadian uranium revenues. In addition, the Canadian government's UF_6 upgrading policy is certain to be an issue in the context of bilateral free-trade talks. While the government appears to be unwilling to eliminate the policy, it could become a point of negotiation if restrictions on Canada's access to the US market materialize.

The Canadian government's involvement in the commercial uranium business occurs on several levels. At the production stage:

1. Foreign investment in production facilities is limited by law.

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2. The government may protect the domestic nuclear program's security of supply by reserving a certain amount of Canadian reserves.

After uranium is produced and sold:

3. The Uranium Export Review Panel reviews the contract, examining its compliance with safeguards (non-proliferation) laws, its pricing terms, and including any applications for exemption from upgrading requirements, pending granting approval of the deal.

4. The Atomic Energy Control Board then reviews the findings of the UERB, generally granting approval and issuing an export permit.

Although it is possible some aspects of Canadian government involvement in uranium production and sales will gradually diminish, the influence of politics and economics on the uranium business in Canada will continue to be great, and merit considerable attention by all observers of the world uranium market.

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ENRICHMENT BLENDING

Introduction

Utilities often hold their uranium inventories in the form of natural uranium. However, as a result of fixed-commitment enrichment contracts, plant delays, and plant cancellations, many utilities hold significant stockpiles of low-enriched UF_6 in their inventories. Many utilities also view this stockpiled enriched UF_6 as less fungible than natural UF_6, and believe that enriched uranium kept in inventory must be at a lower enrichment than that which they ultimately expect to load into the reactor. The assumption is that the inventoried material's lower enrichment can subsequently be upgraded (supplied as enriched feed to an enrichment facility) to the correct enrichment needed for the given reactor reload or first core.

One potential drawback to that strategy is that any future DOE restrictions on the enrichment of non-US-origin feed material probably would apply equally to non-US *enriched* feed material. (Origin of enriched UF_6 is based on the origin of the original feed material.) Some utilities are holding non-US-origin enriched product in their inventories and thus conceivably could be prevented from upgrading it at DOE. The utilities could ship the enriched feed to an overseas enrichment facility, but this might involve contractual disputes with DOE, prohibitive shipping costs, and possible surcharges at other facilities. Enrichment blending is a concept that has been in use by enrichers and fabricators for some time, and it presents a viable alternative to upgrading. Depending on the original enrichment and the enrichment desired, blending costs may be lower than the costs of certain enrichment upgrades.

Enrichment Blending

In theory, enrichment blending is simply the combining of enriched uranium from two input batches having different assays to achieve the desired average product enrichment. For example, blending 10 kgU of 3.4 w/o uranium with 10 kgU of 3.6 w/o uranium will yield 20 kgU of 3.5 w/o product. In this case, there is no loss of feed material, as the equivalent natural uranium contained in the blended product is the sum of the natural uranium necessary to create the ingredients. (No uranium atoms are lost.) However, blending is technically the opposite of the enrichment (or separation) process and some SWU are lost in the blending process.

While it would seem inefficient to "waste" SWU, these losses from blending are small, and their cost may be insignificant compared to the benefits. Figure 3 shows the percentage of product SWU lost if two equal amounts of enriched product are blended to obtain enrichments typical of a 1,000-MWe reactor's reload requirements. SWU lost by blending represent only about 0.01 percent of the SWU contained in the input batches. Assuming each SWU is worth $80, this represents a loss of approximately $800 out of almost $7 million worth of SWU.

Blending losses depend upon the difference between the ingredient enrichment levels; i.e., in blending 3.4 w/o and 3.6 w/o material (having a difference of 0.2 w/o) to obtain 3.5 w/o product, the theoretical loss would amount to slightly less than 0.01 percent of the equivalent SWU contained in the product (Table 3). However, the larger the difference in

Table 3

ENRICHMENT BLENDING EXAMPLE

Ingredient 1		Ingredient 2		Product
10,000 kgU of UF_6e at 3.40 w/o	+	10,000 kgU of UF_6e at 3.60 w/o	=	20,000 kgU of UF_6e at 3.50 w/o
Equivalent to* 75,430 kgU feed 41,540 SWU		Equivalent to* 80,290 kgU feed 45,250 SWU		Equivalent to* 155,720 kgU feed 86,780 SWU

Net Feed gain/loss = 75,430 + 80,290 − 155,720 = 0

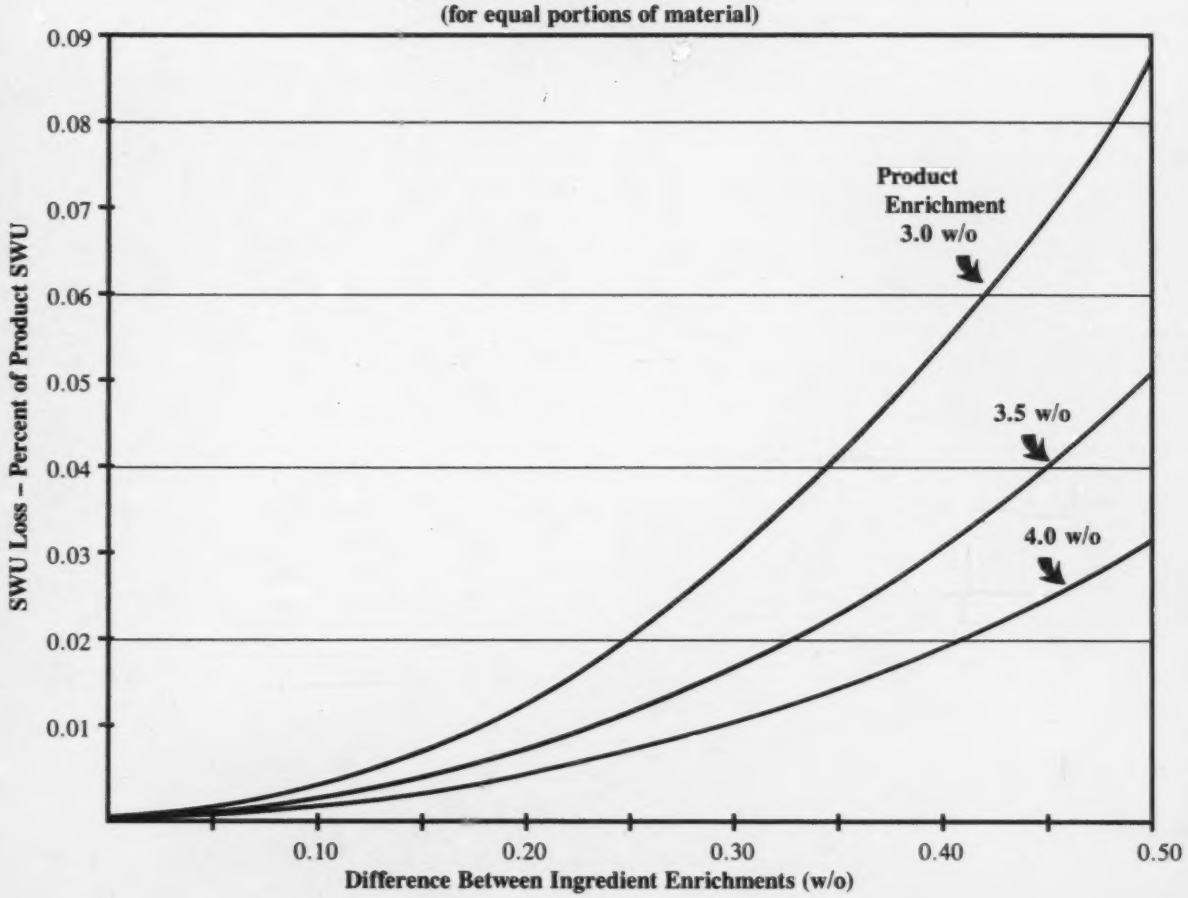
Net SWU gain/loss = 41,540 + 45,250 − 86,780 = −10

Percentage SWU loss = 10/(41,540 + 45,250) × 100 = 0.01152%

* at 0.3 w/o tails assay

Figure 3

ENRICHMENT BLENDING LOSSES
(for equal portions of material)



enrichments between the ingredients, the higher the losses. Thus, if 3.3 w/o and 3.7 w/o materials (having a difference of 0.4 w/o) were blended in equal quantities, the loss would be about 0.03 percent of the equivalent SWU contained in the product, or about $2,500 worth of SWU using the above 1,000-MWe reactor and $80 per SWU example.

SWU losses from blending should be considered in terms of the *relative* cost of upgrading enriched material to the required design level. For example, assuming a utility has inventories of enriched uranium at 3.20, 3.60, and 4.00 w/o, the utility could blend a combination to obtain any product enrichment betweeen 3.20 and 4.00 w/o. The alternative consists of feeding an enrichment plant with 3.20 w/o or 3.60 w/o and performing additional separative work to increase the product enrichment to the desired level. In Figure 4, the losses in the blending process are shown as a percentage of the required upgrade SWU.

Assuming that there are no surcharges or extra costs for the upgrading of enriched product, the upgrade alternative is most attractive if the desired product enrichment is only slightly above the enrichment level of one of the inventoried materials, so that the fewest upgrade SWU are required. The blending option becomes more attractive as the desired product enrichment increases over the enrichment level of the material held in inventory, a situation that would require increasingly more SWU for upgrading. However, even in the worst case, the losses are equal to less than 3 percent of the value of the required upgrade SWU. Therefore, if the SWU

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held in inventory is valued at three or more percent below the cost of upgrade SWU, the blending process would always be less expensive than upgrading. Blending losses could be further reduced by holding the inventory in more closely-spaced enrichment categories, although that could increase inventory holding costs and possibly decrease inventory flexibility.

Blending to Reduce Design Lead Time

Enrichment blending can reduce the nuclear fuel design lead time, an advantage which may in itself be attractive enough to induce utilities to maintain enriched product inventories and blend them to achieve final design requirements. The design lead time for a typical reload fuel batch is shown in Table 4. For a reactor using annual refueling, in which the reactor may operate for 10 months and spend 2 months undergoing refueling and maintenance, the design-enrichment-fabrication cycle requires a considerable amount of time to finalize the design parameters before the plant is restarted from the previous refueling outage. If the actual operations are different than the design projections, this may cause reduced uranium utilization, reduced operating margins, and/or reduced power capability. The reduction in uranium utilization efficiency is significant; actual discharge exposure of fuel is on average 3-5 percent less than the theoretical exposure, and a significant portion of the lost efficiency can be attributed to the conservatism required when designing fuel enrichment levels prior to establishment of the actual operating parameters.

It would be possible to reduce the design lead time with a blending facility, by keeping stocks of enriched uranium at standard enrichments, and then blending to meet utility specifications. For example, assume that each fabricator has a blending facility with inventories of enriched uranium from 1.6 w/o to 4.4 w/o U_{235} at 0.40 w/o intervals. These stocks could be blended on short notice to obtain almost any enrichment required for power reactors.

Markets for Blending as an Alternative to Upgrading

There are two potential markets for blending as an alternative to upgrading:

1. *DOE customers* — The US Tenth Circuit Court of Appeals is currently considering a decision which obligates DOE to restrict the enrichment of non-US-origin uranium destined for use in US reactors. If the decision is upheld, this restriction also probably will apply to upgrading enriched UF_6 (UF_{6e}) inventories. US utilities wanting to upgrade the enrichment level of their non-US-origin UF_{6e} could be forced

Figure 4

BLENDING VERSUS UPGRADING
(Blending stock: 3.2 - 3.6 - 4.0 w/o)

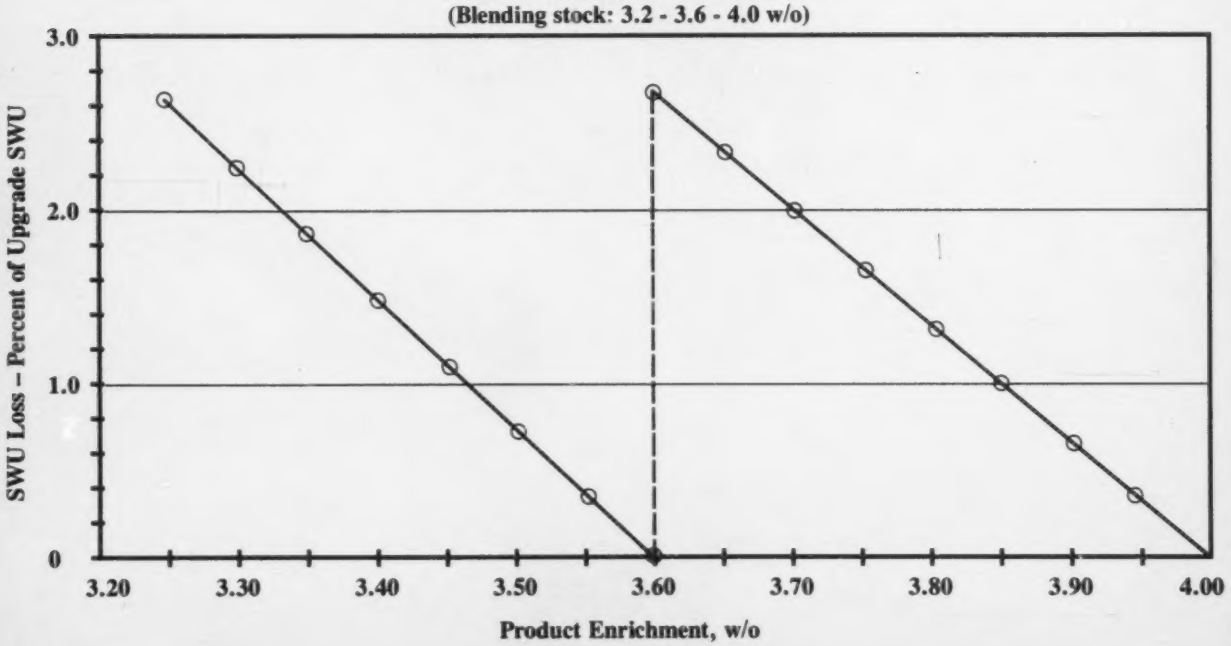

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Table 4

TYPICAL SCHEDULE FOR NUCLEAR FUEL DESIGN

Time (Months)	Schedule
0	Utility provides nuclear fuel designer with shutdown exposure and energy requirements for following cycle.
1	Designer provides utility with information about required enrichment and quantity. Utility provides enrichment supplier with 180-day notice.
7	Enrichment supplier delivers enriched UF_6 to fabricator. Designer completes licensing analysis and confirms applicability of design.
10-11	Fabricator delivers reload batch to site.
11-12	Fuel is inspected and made ready for loading.

to ship their material to Europe for upgrading. In addition to the transportation expense involved, procurement of non-DOE enrichment services may be in conflict with existing DOE enrichment contracts. Utilities planning to purchase UF_6 inventories of canceled plants and have the material upgraded at DOE could be similarly affected.

2. *Non-DOE customers* — While DOE does not have a surcharge for enriched feed material, at least one European enrichment supplier has a upgrade surcharge equal to 2 percent of the current price of the SWU contained in the feed. For the material in the above example (Table 3), this surcharge would amount to between US$175,000 and $250,000, depending on current prices. Faced with this surcharge, one European utility recently found it advantageous to transport enriched feed from Europe to DOE for upgrading, and then retransport the upgraded material to Europe. The shipping costs for UF_6 across the Atlantic and back total about $0.30 per SWU, or about $25,000 for the material in the example. Blending is potentially much cheaper than either of these alternatives, since the losses incurred through blending would total only about $1,000 to $3,000.

DOE has developed a tentative proposal to blend enrichments, currently referred to as its "REFLEX" program. Under the program, DOE would keep stocks of enriched uranium at each US fabricator, and the fabricator would blend the proper enrichment from the stocks as part of the fabrication process. The REFLEX program has the potential of cutting the design-enrichment-fabrication cycle by up to 180 days, and DOE has indicated that the efficiency gained by standardizing enrichments at the enrichment facility would allow DOE to absorb the SWU lost in the blending process at no cost to their customers. The REFLEX program could require establishment of blending facilities at fabricators which currently do not have them, but UF_6 blending facilities are relatively simple and inexpensive compared to the benefits of such a program.

Conclusion

Enrichment blending is not a common technique for increasing the enrichment levels of inventoried material, but it is one that may offer a cost-effective and time-saving way of achieving desired enrichment levels. SWU "losses" incurred in the blending process generally are slight and may be insignificant relative to the overall cost of upgrading to a specific design level. As an option to upgrading, blending could potentially become more attractive to DOE customers if restrictions are placed on upgrading non-US-origin enriched product at DOE facilities.

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DECOMMISSIONING OF NUCLEAR PLANTS, PART 2

Part one of this two-part article appeared in Report 226, June 1987.

Introduction

The presence of significant levels of radiation makes the decommissioning of nuclear power plants much more difficult than the decommissioning of fossil-fueled plants. Decommissioning work done to date has shown that nearly all of the radioactivity in a plant after shutdown and defueling comes from neutron-activated materials of the reactor pressure vessel and internal parts, biological shielding, and containment structure. Cobalt-60, a radioactive isotope with a half-life of about 5 years, is formed mainly in steels and dominates the radiation spectrum of the plant for at least 50 years after shutdown. Even though nearly all the radioactivity is found in the central plant area, less than ten percent of the volume of radioactive waste products come from these activated materials. Surface contaminated materials of considerably lower radioactivity account for the great majority of waste.

Much of the technology necessary for dismantling nuclear plants is already in existence or under development. Various techniques and tools for cutting apart equipment and for decontaminating radioactive surfaces are already in use, and are being refined. The need for remote systems in decommissioning work depends greatly upon the length of time a plant is to be stored before initiating the dismantling process. The longer the radioactive isotopes are given to decay, the greater the role humans will have in doing the work. Already, robotic technology is being developed for use in nuclear plants, for regular monitoring and inspection, for maintenance, and for future dismantling.

Many decommissioning cost studies have been conducted over the past decade. While there are substantial variations, most studies of large-scale commercial plants estimate the costs of fully decommissioning a nuclear unit at between $100 and $200 million. Two variables in particular have the potential to greatly increase these costs — higher costs for waste disposal and higher costs for regulatory compliance. Waste disposal costs have risen dramatically in recent years, especially in the USA, and commercial decommissioning of a number of plants could lead to much increased regulatory activity.

Radiological Considerations

The presence of radiation adds unusual hazards to decommissioning of nuclear power plants. Other than the nuclear fuel, nuclear plant components and materials are made radioactive either by *contamination* or by *neutron activation*. Each type poses different challenges and each affects the schedule for decommissioning in different ways. Radioactivity coming from contamination occurs primarily on the material surfaces, by physical contact with other radioactive substances. By contrast, certain materials become activated through exposure to neutron radiation, which creates radioactive isotopes of some of the elements that constitute the material. Thus, while a contaminated surface may often be rendered "clean" (within established standards) by treating the surface, the radioactivity in an activated material is integral to the atomic structure of the material and cannot be altered except by the natural decay of the active isotopes. It is estimated that in light-water reactors, as much as 99 percent of the unit's total inventory of residual radioactivity is produced from neutron activation, nearly all of which is found in the reactor's pressure vessel and internal parts, biological shielding, and nuclear steam supply system.

Dealing with the radiation hazards found in the highly activated materials of the reactor's pressure vessel, primary cooling system and shielding imposes a different set of problems than those needed for surface decontamination. Many of the isotopes are highly unstable, and some have half-lives that are orders of magnitudes longer than the human lifespan. The steel alloys used to make the reactor pressure vessel and supporting structures, as well as steel used to reinforce the concrete shielding and containment structure, contain substantial amounts of cobalt and nickel. Isotopes of these elements — Cobalt-60 and Nickel-59 — are two of the principal products formed by neutron radiation.

The most significant residual activation product present in the plant's central reactor area is Cobalt-60. It is a strong gamma radiation emitter with a comparatively short half-life of 5.3 years, and is a component or trace-element of nearly all steels, especially stainless steels.* Cobalt-60 dominates the radionuclide inventory over the first hundred years after plant shutdown, even though after 53 years (10 half-lives) its radioactivity level is only 0.1 percent of that found at the time of shutdown (Figure 5). Experience from the UK's Windscale decommissioning project has shown that while stainless steel components account for only about five percent of the mass in the reactor, they are responsible for about 75 percent of the residual radioactivity.

* The three types of radiation emitted in the decay of radioactive materials are alpha, beta, and gamma radiations. Alpha radiation consists of the emission of helium nuclei (2 protons and 2 neutrons). Beta radiation consists of the emission of free electrons, and gamma radiation consists of the emission of electromagnetic energy (similar to X-rays but originating from the nucleus). Half-life refers to the amount of time it takes for a material's radioactivity to diminish by half.

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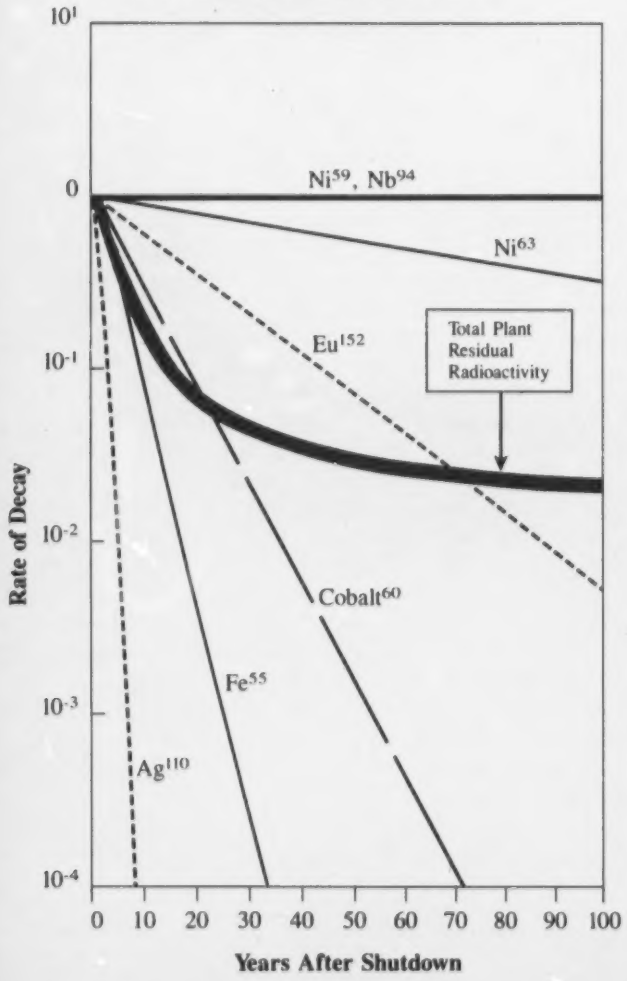
BASIC CONSIDERATIONS

Nickel-59 is produced in smaller quantities and is a comparatively low-energy (beta) emitter, but has a half-life of 80,000 years. Over any of the currently anticipated timeframes for decommissioning, Nickel-59 and other such long-lived isotopes would not undergo any meaningful level of decay, making their disposal more difficult than would be the case for isotopes with relatively short half-lives. Other activation products found in nuclear plant materials include Nickel-63 with a half-life of 100 years, Niobium-94, a gamma-emitter with a half-life of 20,000 years, and Iron-55, an x-ray emitter with a 2.4-year half-life.

Figure 5

DECAY RATES OF SOME COMMON RADIOISOTOPES FOUND IN NUCLEAR PLANT MATERIALS



One problem in estimating future radioactivity levels of activated materials stems from the high degree of variability in the amounts of alloy or trace elements found in plant equipment. Cobalt and niobium concentrations in steel may vary as much as tenfold, and trace elements present in the concrete of containment vessels are especially hard to control. One of the lessons being learned from decommissioning projects is that careful attention to materials specifications, and avoidance, where possible, of the use of cobalt and nickel-intensive alloys such as stainless steels and stellite, can make decommissioning less time-consuming and dangerous.

The amount of radioactivity found in the central areas of a nuclear reactor is primarily a function of the size of the plant and how long it has been operating. Thus far, no full decommissioning projects have been undertaken that closely approximate what will be encountered in dismantling a 1,000-MWe or larger plant that has operated for 30 or more years. The radiation levels in and around the reactor pressure vessel could require remote monitoring, inspection and dismantling for at least fifty years after plant shutdown.

Disposing of Decommissioned Plants

As the country with the most nuclear plants, the USA's efforts to solve the problems of waste disposal have been closely watched by the other nuclear nations. For high-level waste, the US government took a significant step forward when it passed the Nuclear Waste Policy Act of 1982, legislation directed toward the site selection and construction of at least one geologic repository for highly radioactive nuclear waste. The proposed repository program has since encountered a number of obstacles, and although some progress has been made, the program may be in jeopardy. But aside from the problems of the repository program, the nuclear wastes it is meant to handle consist almost exclusively of spent reactor fuel; little or no provision has been made for high-level decommissioning wastes. Even excluding reactor spent fuel from decommissioning wastes, the volumes of low, medium, and high-level wastes from one large commercial plant alone are substantial.

In 1978, NRC estimates for a reference 1,100-MWe PWR showed the bulk of low-level waste products coming from surface contaminated materials; about 16,000 cubic meters of contaminated metal and concrete are in this category. In addition, nearly 1,200 cubic meters of activated metal and concrete, and approximately 600 cubic meters of other radioactive products are included in low-level waste estimates, for a total of about 18,000 cubic meters (Figure 6). For perspective, this is about 1.5 times the amount of other low-level wastes generated during the reference plant's operating lifetime, and is equal to about one-fourth of the total low-level

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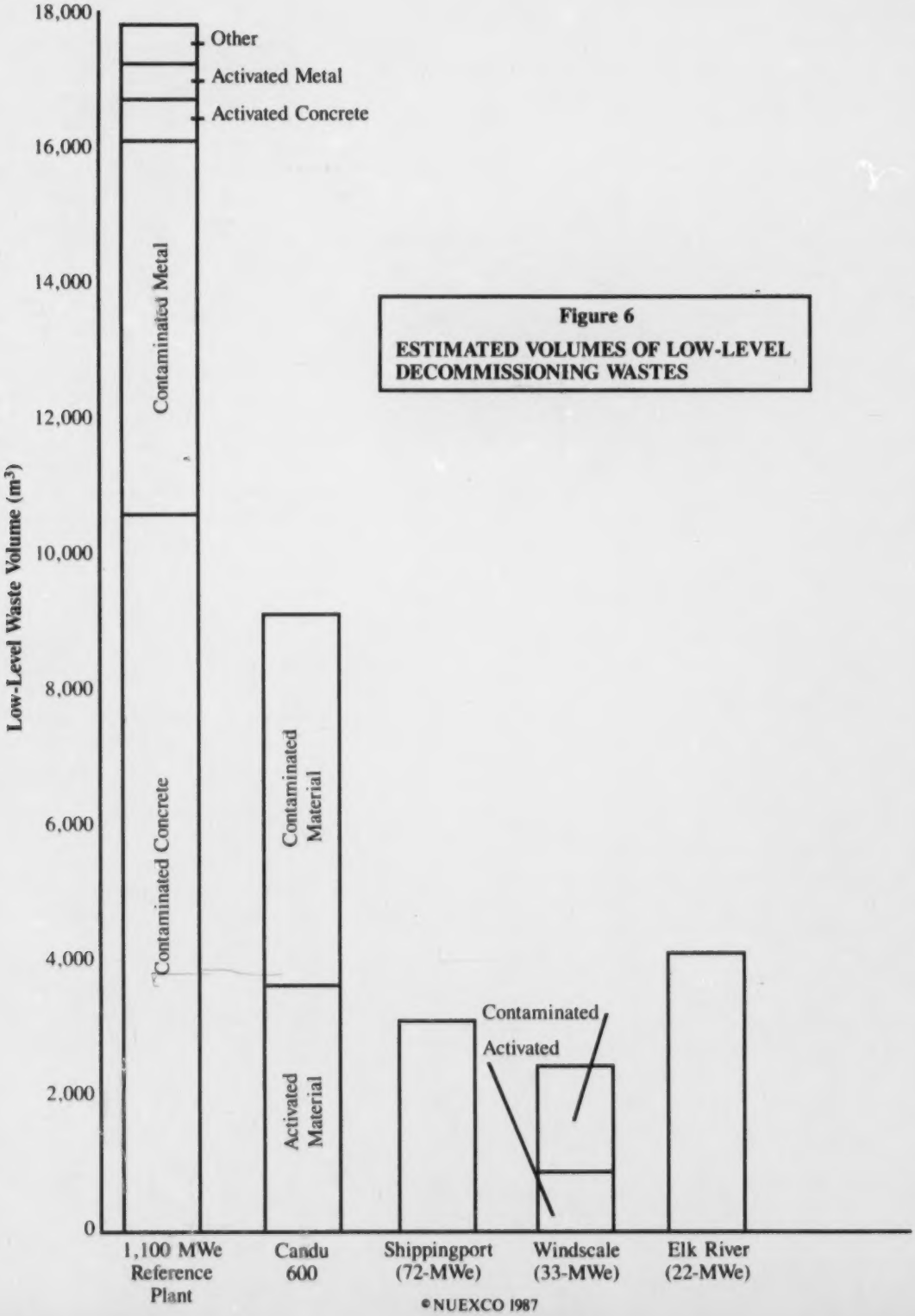

Figure 6

ESTIMATED VOLUMES OF LOW-LEVEL DECOMMISSIONING WASTES

radioactive waste shipped to commercial US waste dumps every year. Thus, decommissioning four commercial-size reactors per year would approximately double the present annual volume of low-level waste shipped to disposal sites in the USA.

Nearly all intermediate and high-level waste comes from the reactor pressure vessel and internal parts. Of the total plant waste, it is estimated that *less than seven percent* by volume will be of activated materials, which constitute nearly all of the plant's residual radioactivity. Those materials alone will require shipping in gamma-shielded containers. How long a plant is kept stored before dismantling is attempted has a great bearing on the amount of radioactivity (and therefore the categories of wastes) that will be encountered. According to recent NRC estimates, three years after shutdown total residual radioactivity in a 1,175-MWe reference PWR drops from approximately 4.9 million curies to 2.5 million curies. After 100 years, the total activity level is estimated to diminish to about 100,000 curies.

Given the very limited availability and capacity of waste dump sites in the USA, and in other countries as well, it is questionable whether, at present, even one large commercial nuclear plant can be dismantled fully. Without greatly increased access to disposal facilities, long-term storage or entombment may be the only real alternatives for the near future.

Decontaminating Plant Equipment

Decontamination methods have been highly developed for plant maintenance and equipment disposal. Although more than 90 percent of a decommissioned nuclear plant's waste volume comes from equipment and materials affected by surface contamination, only about one percent of the plant's total residual radiation is found on this contaminated material. The aim of decontaminating a surface is to reduce the level of radioactivity so that the equipment or material can be reused, to reduce personnel exposure during decommissioning procedures, or to reduce waste volume. Much or all of the surface's radioactivity will be entrained in the effluents or products of the decontamination process, reducing waste volume. Even though the amount of radioactivity found in contaminated material is so much less than that found in activated products, it is spread over many types of components. A judgment may have to be made as to whether it is worth the cost to decontaminate the material or equipment in question. It may be cheaper simply to dispose of the material as low-level waste. However, because the costs of waste disposal are a function of volume, if a large volume of material can be decontaminated, substantial cost savings could be realized.

Before decontamination procedures can begin, a thorough evaluation must be made of the materials' chemical nature, types of radionuclides present, and penetration depth of surface contamination. Only then can the operators of a decommissioning project select the best (of the many possible) techniques for the surface in question. In choosing decontamination methods, efficiency is judged by a combination of costs, effectiveness, and minimum production of contaminated particles, aerosols, or fluids that themselves become radioactive wastes.

Most nuclear plant waste materials that must be decontaminated are either concrete or steel. Generally, since radioactivity comes from particles deposited on the material's surface and does not penetrate into the material, decontaminating involves removing the surface deposits or surface layer of the material. Normally, chemical or mechanical methods are used for surface treatment. Chemical techniques normally are used for metal surfaces while mechanical methods may be used either for concrete or metal. Chemical methods are classified by their degree of aggressiveness, and often the more aggressive the method, the more difficult the treatment of the waste produced by the process. The operator must consider whether to decontaminate the equipment or material in-place or to dismantle and remove it from the reactor or plant area, in order to better control the cycling of the chemicals. Under controlled shop conditions, the creation of excess effluents can be minimized. Some common methods include using ultrasound in conjunction with chemicals to loosen contamination in crevices, electro-mechanical "pickling" to control the depth of surface removal, and the use of liquid freon to penetrate very small fissures and holes.

Mechanical decontamination can be used on all surfaces, by grinding, brushing, or abrading the surface. These methods tend to create substantial amounts of particulate waste products, whose dispersion may be difficult to control. Other methods may be required for cases of deep surface penetration, such as in rough concrete. High pressure abrasive jets, using water or glycerine, may be required, or the use of oxygen or plasma-arc torches, or even high-frequency microwaves. In all cases, the decontamination procedure must account for containment of waste smoke, fluids, particles and other debris.

Technology for Dismantling

Dismantling the radioactive parts of a nuclear plant involves a great deal of unbolting, cutting, and perhaps even the use of explosives to reduce the pieces to a manageable size for removal to waste disposal sites. Whether the dismantling can be done by plant personnel or by means of remote or robotic equipment will depend on the radioactivity level.

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Much of the material in the reactor will have to be cut apart, probably using acetylene or other types of torches. The thickness of materials can vary greatly — from steel no more than a couple of millimeters thick to a PWR reactor pressure vessel with a thickness of 300 to 600 mm. Reinforced concrete may be as much as several meters thick. With such variable materials, which will exhibit various degrees of contamination and activation, specialized equipment will have to be used. The choice of method and equipment must minimize the amount of uncontrolled aerosols, smoke, particles or fluids that are dispersed, and the equipment itself must resist contamination and allow easy cleaning.

Either thermal (including electrothermal) methods or mechanical cutting methods may be considered for most materials. Thermal cutting includes oxygen torches, electrothermal lances, or plasma-arc devices. Mechanical techniques involve various types of saws, abrasive wheels or disks, drills, pneumatic or hydraulic hammers, or abrasive high-pressure water jets. Thermal cutting methods generate substantial quantities of aerosol materials, while mechanical devices generate solid particulates or liquid effluents. Other methods may also be used selectively. Lasers have the potential to cut steel or concrete, and directional, highly controllable explosives are being considered for certain types of demolition.

In the United Kingdom, two methods are approaching the demonstration phase on the Windscale AGR decommissioning project. The first, being developed by the UK Atomic Energy Authority in conjunction with the engineering firm Strachan & Henshaw, is a 2.5-meter diameter diamond-tipped circular saw, capable of cutting to a one-meter depth in concrete. This saw is mounted on a crane, and is intended to cut the reactor's containment shell. The second method involves what is termed the remote dismantling machine. This machine will consist of a rotating shield platform mounted above the reactor and a rigid mast containing a manipulator arm that descends into the reactor vault. The manipulator arm will carry cutting tools, such as an oxygen-propane torch with an iron powder injection system for cutting stainless steels, and will segment all material, and transfer it to racks or baskets that can be removed to the special waste packaging building that is part of the project. The remote dismantling machine is scheduled to begin operating in 1991, and disassembly of the reactor pressure vessel and internal parts will continue for several years.

In Japan, the Japan Atomic Energy Research Institute (JAERI) at Tokai is involved in development of a number of cutting tools, as part of an overall program to create plant decommissioning technology. An experimental plasma-arc cutting machine is under development for use on the Japan Power Demonstration Reactor's (JPDR) pressure vessel. The 12.5-MWe BWR was shut down in 1976 after 13 years of operation. JAERI expects to use the $2.5 million tool to cut a mockup pressure vessel, continuing through the summer of 1987, before attempting to work of the actual pressure vessel. The plasma-arc saw operates by passing a high-voltage direct current between a rotating "blade" electrode and the material to be cut, generating a moving arc in a gas atmosphere. The tool will cut up to 200 mm-thick steel, operating under water and using argon and hydrogen or nitrogen gas. Segmenting the reactor pressure vessel and core equipment is scheduled for 1988.

JAERI also is testing methods for cutting or demolishing the neutron-activated concrete biological shielding at JPDR. The machinery chosen must be compact, to operate within the containment structure, and must minimize airborne particulate and aerosol materials. Some of the methods being evaluated are kerosene-oxygen flame jet cutting, mechanical cutting with diamond-tipped saws, highly controlled explosive charges, and laser cutting techniques. Other organizations in Japan are testing the use of arc gouging and oxygen gas tools for cutting steels and disc or wheel-type cutters and shearing tools for concrete.

Remote Technology in Decommissioning

Almost regardless of the length of time a reactor is allowed to "cool off" before decommissioning is attempted, dismantling its high-radiation central areas will require the use of remote systems. Development of both fixed-position and mobile "robots" has been underway for some years in a great many industries and for various applications. Many types of robots have been developed for use in nuclear power plants, and some of these will be readily adaptable to the requirements of plant decommissioning. Robotic technology is used for various reasons, but the primary one is to reduce radiation exposure to workers, and to perform operations that would not be achievable by ordinary methods. In the case of decommissioning, robots also will allow a drastic reduction in the length of time a plant must be stored before it can be dismantled, and could provide a substitute for scarce or unavailable skilled labor.

Since remote devices for decommissioning are intended for use in radioactive environments, they must be designed to conform with certain general requirements.

1. They must be "hardened", so that radiation does not interfere with their operation.

2. They must be easy to decontaminate after exiting from contaminated areas, especially as some operations could result in extensive contamination.

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3. They must be exceptionally reliable and durable, because failure within certain plant areas could make them difficult to retrieve.

4. Depending on their function, they must be highly mobile.

5. The interface with human operators must be simple, effective, and easy to maintain.

The remote devices likely to be used in plant decommissioning fall into a few general categories, each with fairly specific functions and design requirements.

Monitoring, Surveillance and Visual Inspection — Robots for plant radiation monitoring are already entering fairly widespread use in the nuclear industry. Their function often requires a high degree of mobility, and monitoring robots have been designed with treads, wheels, and multiple legs. Some of these are able to climb stairs and maneuver over short walls and other obstacles. Some are self-contained, using batteries for power, and others operate with an umbilical connection providing power and control functions. Monitoring and inspection robots generally do not have to exhibit a high degree of manipulative ability, beyond perhaps taking smear samples on various surfaces. They also need not be large in size, or be able to handle heavy objects; in fact, they tend to be rather small and lightweight, especially those operating under battery power.

Decontamination — Another use of robots is in decontamination. They have already been employed in numerous nuclear plant maintenance operations, and for routine cleaning and decontamination of nuclear steam supply systems and other operating machinery, as well as in post-incident cleanups. These types of operations require the ability to manipulate high-pressure washers, for example, or mechanical scouring systems, and therefore must combine mobility with precision movement and manipulation of tools. Such robots tend not to be battery-operated, but have cable and hose connections supplying power and communications.

Dismantling Equipment — A high-degree of manipulative ability, coupled with a substantial lifting capability, will be needed for robots designed to unbolt and dismantle plant equipment. It remains to be seen whether it will prove more cost effective simply to cut apart or to unbolt much of the piping and valving in a plant.

Cutting Equipment — Robots already are in use as remote welders, operating inside pipes and other areas inaccessible to human welders, and adapting these high-precision robots to perform gas-torch cutting should not prove difficult. Remote-controlled cutting machines generally fall into two types: large, semi-fixed position tools, and highly mobile robotic vehicles. Cutting of pipes, valves and other peripheral equipment thus presents very different requirements from cutting apart thick, highly activated reactor pressure vessels and internal parts, concrete shielding and containments.

Handling and Transporting — Specialized robotic equipment will be needed to lift and move the parts dismantled by cutting equipment, and perhaps decontaminated by other robotic machines. Some of these transport machines probably will be in the form of rail-type, fixed position equipment designed to move already handled parts from the plant floor to a handling area, and from there to a transport area. These may have to be able to lift and move several tons of weight. Other robot handlers will be needed to move pieces of sectioned plant equipment to specified locations for loading into "crates." Most of these robots will have to be able to lift at least 200 kg in weight, and may be programmed to perform in a repetitive manner, similar to existing factory robots of today.

Packaging and Handling Equipment — Separate systems will have to be provided for packaging the radioactive materials removed from the plant, in several waste categories. These systems probably will incorporate volume reduction and compaction machinery and placement equipment, so that sealed casks can be taken from the site directly to disposal areas. Such equipment already is available.

Remotely Operated Construction Equipment — Many tasks can be performed by ordinary construction equipment, such as cranes, backhoes, forklifts, front-end loaders, etc, if they are converted to remote operation. Such conversions are already available for hazardous and underwater construction.

Certain areas have been identified that will need considerable development for use in decommissioning nuclear plants. Most self-contained robots, now largely used for monitoring and inspection, have rather limited operating times. Their battery systems often are capable of no more than one hour of sustained use before the unit must return to where it can be recharged, which may take up to 24 hours. Robots with umbilical connections, essentially a thick cable supplying control connections, power for mechanical systems, and possibly such materials as oxygen and aceteylene for cutting torches, have difficulty maneuvering in tight spaces when tethered to the connecting cable. The cable also has definite practical length limits, making it difficult for robots to climb stairs, turn numerous corners, and still perform disassembly operations.

Many or most operations by robots involve a human operator controlling the motions of the robot through either a wired or radio contact. Effective remote manipulation requires a highly sophisticated interface, with tactile and visual feedback. While it is probable that some operations will be pre-programmed, such as a robot inside a section of

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pipe cutting sections at specified distances, much of the work still will require skilled operator-robot control. Telesensory systems are rapidly evolving and should be quite advanced within a decade, when a greater need for decommissioning of commercial nuclear plants becomes necessary.

One of the greatest tests of robotic technology will probably come not from operating the equipment, but in scheduling of how and when each disassembly operation takes place. Given the complexity of plant plumbing, and the non-standard nature of most plants now in existence, especially in the USA, the precise order of disassembly will be tremendously important. This may seem elementary — the engineers who are familiar with the plant simply work with the schedulers to remove the equipment a little at a time. However, consider the difficulties if a plant is stored or mothballed for 25 to 50 years. There could well be no one available who really knows the plant details after that time has elapsed.

To a great extent, how robots are used will depend on the timeframe of the decommissioning process. Where a need is perceived to move quickly ahead with dismantling, robots will have a relatively greater role than where the plant is to be stored for many years. It is likely that robotic technology will move in the direction required for nuclear plant decommissioning, and that by the time they are needed, robots capable of performing the many tasks involved in plant decommissioning will be widely available and well-adapted to the nuclear industry.

Costs of Decommissioning

Over the past decade numerous studies have been conducted, both by utilities and by other organizations, to determine probable decommissioning costs (Figure 7). These cost estimates have a direct bearing on utilities' arrangements for financing their future decommissioning operations. Given the extensive study of the cost problem, the many details and phases involved are well known. Nevertheless, the available literature on decommissioning costs suggests a wide range of estimates. A major problem in judging the reliability of such estimates is the lack of uniformity in methodologies, and the variables affecting every estimate.

Some of the variables involved in estimating decommissioning costs include:

1. Lack of standardization among nuclear plants;
2. Lack of standardization among cost studies;
3. Differences between generic and site-specific studies;
4. Difficulty in estimating future costs of waste disposal;
5. Uncertain development costs for remote and other specialized tools and equipment;
6. Difficulties in estimating inflation over a prolonged period of storage or entombment, which may be up to a 100 years;
7. Uncertain future regulatory changes;
8. Differences in actual plant types and operating history;
9. Different planned stages of dismantling and timetables for achieving full decommissioning.

To date, no large commercial reactors anywhere in the world have been completely dismantled. In the USA, only the Shippingport, Pennsylvania reactor (jointly owned by DOE and the Duquesne Light Company) is undergoing active decommissioning, and while it will certainly provide considerable cost data, it may not be representative of costs that will be encountered in later, larger projects. The pressure vessel and internal parts of the Shippingport unit are being shipped intact to the Hanford reservation for intact disposal, rather than being segmented and disposed of in a manner similar to what operators will use for large plants. Also, at 72 MWe, it is less than one-tenth the size of most commercial reactors. Decommissioning the Shippingport reactor is expected to cost about $100 million. While much experience will be gained at Shippingport, it is difficult to determine its applicability in estimating costs of large commercial units.

Despite the uncertainties, several very detailed cost studies are available, and give some indication of the probable costs. In 1978, the US Nuclear Regulatory Commission (NRC) commissioned the Battelle Pacific Northwest Laboratory to conduct a study aimed at defining the costs of decommissioning a reference PWR and BWR plant, both having 1,100-MWe capacity. This study was revised and updated in 1984. Also, the Atomic Industrial Forum (AIF) prepared an evaluation of decommissioning costs, which it published in 1983. Several nuclear utilities, such as Canada's Ontario Hydro and the UK's South of Scotland Electricity Board also have released detailed cost studies for decommissioning their own plants.

The updated Battelle cost estimates for reference 1,100-MWe PWRs and BWRs were $104 and $133 million respectively (in constant 1984 US dollars); the estimates assumed immediate dismantlement through Stage 3, with a 25-percent contingency factor. A comparative *site-specific* category showed higher costs for the PWR case ($140 million in 1984 constant dollars), while the BWR remained essentially unchanged at $134 million. If instead of immediate dismantlement, a 50-year safe storage period is used for the generic PWR case, the cost drops to about $97 million, and for a 100-year entombment scenario the cost declines further, to about $84 million, both in 1984 constant dollars.

Studies conducted by the AIF estimate costs for immediately dismantling both types of plant to be much lower. The PWR case average is projected to be $54 million, with a high estimate of $102 million and a low estimate of $24 million; in the case of the BWR costs average $65 million, ranging from

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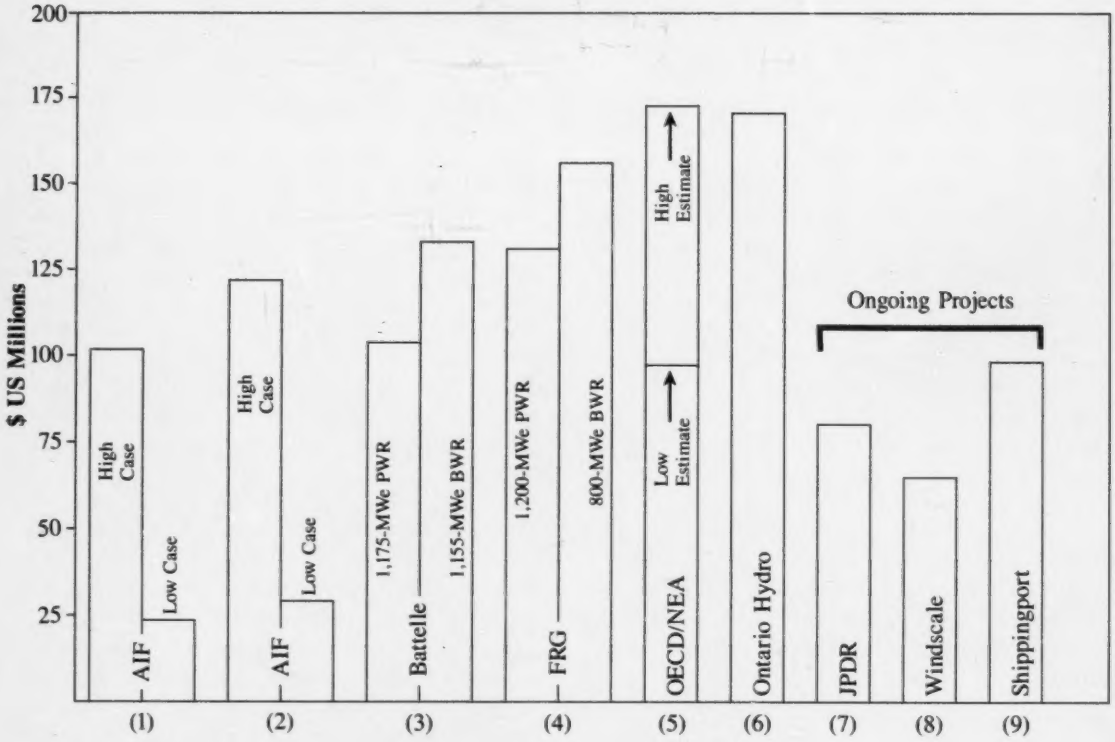
BASIC CONSIDERATIONS

Figure 7

SELECTED COST ESTIMATES FOR NUCLEAR PLANT DECOMMISSIONING



1. AIF estimate for immediate dismantlement of large PWR, constant 1980 US dollars.

2. AIF estimate for immediate dismantlement of large BWR, constant 1980 US dollars.

3. Battelle Pacific Northwest Laboratory estimate for immediate dismantlement of reference PWR, and BWR, constant 1984 US dollars.

4. Association of German Electric Power Utilities estimate for immediate dismantlement of reference 1,200-MWe PWR and 800-MWe BWR, constant 1984 US dollars.

5. OECD/NEA survey, cost estimates for immediate dismantlement of 1,300-MWe LWR, constant 1984 US dollars.

6. Ontario Hydro estimate for immediate dismantlement of Pickering Unit 1, 500-MWe Candu, constant 1980 US dollars.

7. Japan Power Demonstration Reactor (JPDR, 12.5-MWe BWR) cost estimate, undergoing decommissioning.

8. UK Atomic Energy Authority Windscale project (33-MWe AGR) cost estimate, undergoing decommissioning.

9. US DOE Shippingport Reactor (72-MWe PWR) cost estimate, undergoing decommissioning.

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a high of $122 million to a low of $29 million. For decommissioning to a Stage 1 condition, or mothballing, the PWR averages about $6 million and the BWR averages about $9 million. Entombment costs are estimated to lie between mothballing and immediate dismantlement — the PWR case averages $14 million and the BWR $24 million. AIF notes that the fourfold difference in estimated costs between high and low projections are due to differences in labor rates, plant size and configuration, whether spent fuel is considered part of decommissioning, waste transport variables, inclusion or exclusion of engineering and planning, and variations in degree of required dismantling.

A study made by Ontario Hydro estimated costs for immediate dismantlement of its Pickering Unit 1 (515-MWe CANDU) of about C$200 million, in 1980 Canadian dollars (about US$170 million in 1980). Ontario Hydro's figures include a 10-percent contingency factor and do not consider fuel disposal costs in decommissioning costs. Another study by the South of Scotland Electricity Board (SSEB) showed costs of immediately dismantling its Hunterston Unit B1 (625-MWe AGR) to be 270 million pounds sterling, in 1982 values (over US$500 million in 1982). Other studies by the Association of German Electric Power Utilities, and the Swedish Nuclear Power Inspectorate estimate decommissioning costs of large-scale PWRs to be $130 million and $126 million (in 1984 dollars) respectively. Other industry estimates of decommissioning costs cover a wide range, from 10 percent up to 40 percent of original construction costs.

Current decommissioning estimates for large-size commercial plants generally range between $100 to $200 million. With such a wide spread of cost estimates, and so many variables affecting future costs, it is important to remember the unanticipated escalation in nuclear plant construction costs that took place from the 1970s through the present. To a large extent, nuclear plant decommissioning is a developing technology, which could well be affected by some of the same uncertainties that affected the nuclear construction industry.

Even if the mechanical and engineering aspects of plant decommissioning are reasonably amenable to accurate cost estimating, two areas in particular could account for large future cost increases — costs of waste disposal, and increases due to regulatory change. Between 1980 and 1983, for example, disposal costs of low-level wastes at the disposal site at Barnwell, South Carolina increased more than 600 percent. Since in several of the decomissioning cost estimates, low-level waste disposal accounted for up to or above 40 percent of the total cost, large future increases in disposal costs could affect overall decommissioning costs dramatically.

It is equally difficult to predict how future regulatory trends will affect decommissioning. It is possible that the initiation of several large, commercial decommissioning projects could focus attention on gaps in regulatory procedures, resulting in new rounds of rulemaking and attempts at compliance, with the associated unpredictible and costly effects that characterized the emergence of the nuclear construction industry. In essence, the one aspect of decomissioning cost estimating that stands out is the need for caution in accepting any of the current figures. Perhaps they will prove to be accurate, and they may even decrease with time as economies of scale, maturing technologies, and actual experience enter the picture. Conversely, substantial escalation of costs also is a real possibility.

Conclusion

Since the residual radioactivity in a nuclear plant continues to inhibit much of the direct labor in the dismantling process for a minimum of 50 to 100 years after shutdown, some remote technology must be used to decommission the plants. To some extent, that technology now exists, and extensive development is underway in several countries and on at least two decommissioning projects. Both the Windscale and the Japan Power Demonstration Reactor projects will provide much-needed experience in plant decommissioning methods and uses of technology.

One of the least certain aspects of nuclear plant decommissioning is how much it will cost. While numerous studies have been conducted, most of which estimate costs of between $100 and $200 million for typical, large-scale commercial units, two varibles — waste disposal costs and costs incurred due to possible future regulatory changes — could be especially subject to substantial escalation.

The units currently being decommissioned are small by the standards of today's large commercial reactors. Until more experience is gained decommissioning plants representative of the mainstream commercial reactor base, both in size and in operating time, estimating the technical problems and costs will be extremely difficult.

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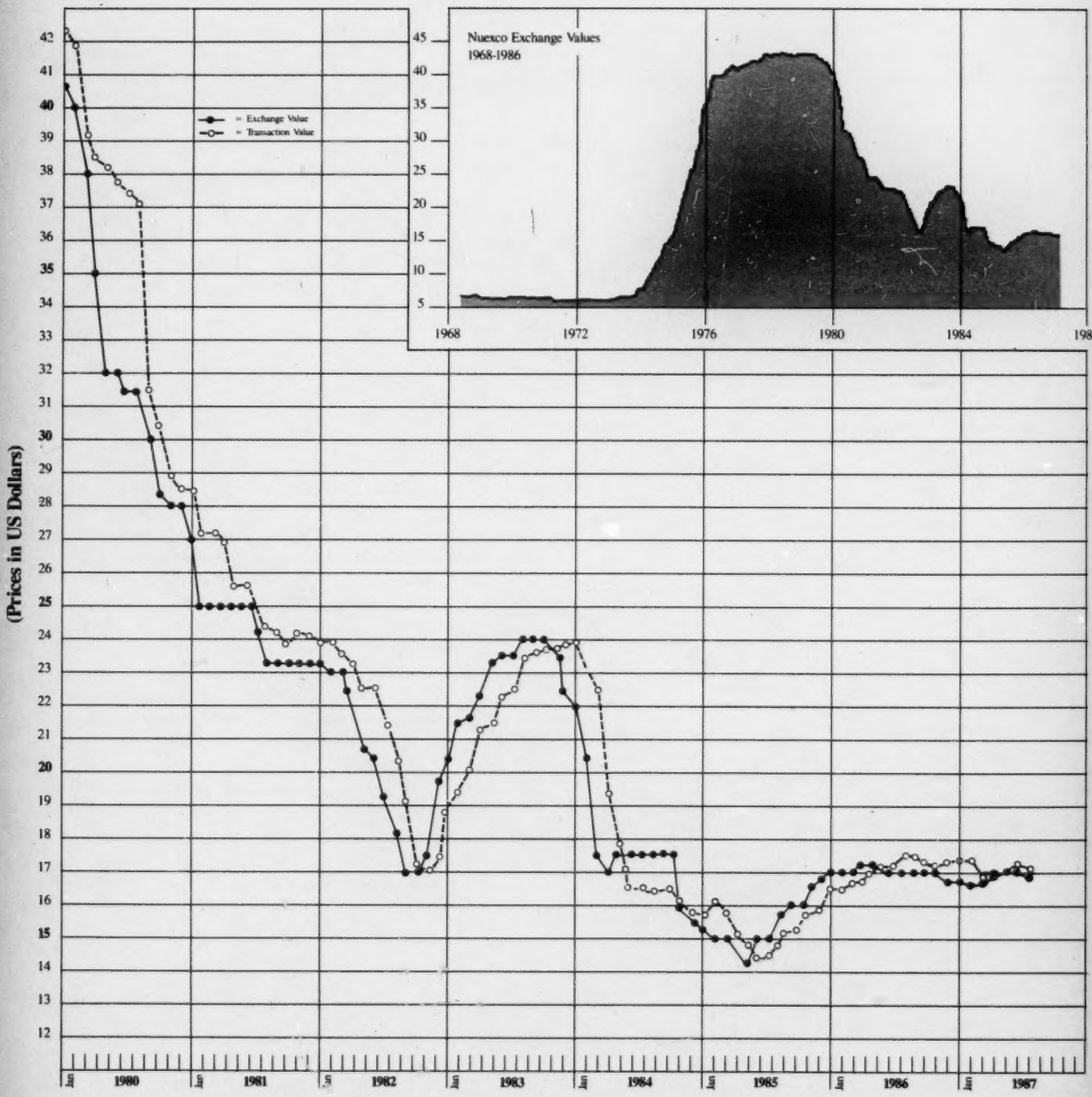
HISTORICAL MARKET DATA



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HISTORICAL EXCHANGE VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U_3O_8)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968	—	—	—	—	—	—	—	6.35	6.35	6.40	6.45	6.50
1969	—	6.35	6.10	6.10	6.25	6.25	6.20	6.20	6.15	6.15	6.15	6.20
1970	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.20	6.15	6.15	6.15	6.15
1971	6.20	6.20	6.20	6.20	6.15	6.05	6.00	5.95	5.95	5.95	5.95	5.95
1972	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95
1973	5.95	6.00	6.10	6.20	6.45	6.50	6.50	6.50	6.50	6.50	6.75	7.00
1974	7.70	7.90	8.00	9.00	9.50	10.50	11.50	12.00	12.50	14.00	14.75	15.00
1975	16.00	16.00	18.00	20.00	21.00	23.00	24.70	26.00	26.00	28.50	30.00	35.00
1976	35.20	37.00	39.25	40.00	40.00	40.00	40.00	40.40	41.00	41.00	41.50	41.00
1977	41.35	41.50	41.60	41.60	42.00	42.25	42.25	42.25	42.40	42.75	43.20	43.20
1978	42.90	43.25	43.25	43.25	43.40	43.40	43.40	43.10	43.25	43.00	43.25	43.25
1979	43.25	43.25	43.25	43.25	43.25	43.00	42.70	42.70	42.20	42.20	41.00	40.75
1980	40.00	38.00	35.00	32.00	32.00	31.50	31.50	30.00	28.50	28.00	28.00	27.00
1981	25.00	25.00	25.00	25.00	25.00	24.25	23.50	23.50	23.50	23.50	23.50	23.50
1982	23.00	23.00	22.50	20.75	20.50	19.25	18.25	17.00	17.00	17.50	19.75	20.25
1983	21.50	21.75	22.25	23.25	23.50	23.50	24.00	24.00	24.00	23.50	22.50	22.00
1984	20.50	17.50	17.00	17.75	17.75	17.50	17.50	17.50	17.50	16.00	15.50	15.25
1985	15.00	15.00	15.00	14.25	15.00	15.00	15.75	16.00	16.00	16.50	16.75	17.00
1986	17.00	17.00	17.25	17.25	17.00	17.00	17.00	17.00	17.00	17.00	16.75	16.75
1987	16.65	16.75	17.00	17.00	17.00	**16.90**						

HISTORICAL TRANSACTION VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U_3O_8)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	—	—	—	—	39.60	39.70	39.70	40.40	40.30	40.60	40.70	40.70
1977	41.30	41.30	41.40	41.50	42.80	42.90	43.00	42.60	42.50	42.80	42.90	42.90
1978	43.10	43.30	43.70	43.60	43.60	43.20	43.30	43.40	43.40	43.60	43.40	43.70
1979	43.60	43.80	43.70	43.40	43.60	43.70	43.70	43.60	43.60	43.60	43.50	42.30
1980	42.00	39.30	38.60	38.40	37.90	37.60	37.30	31.60	30.60	29.00	28.70	27.70
1981	27.20	27.20	27.00	25.70	25.70	24.50	24.40	24.30	23.90	24.10	24.10	24.00
1982	24.00	23.70	23.40	22.60	22.70	21.50	20.30	19.10	17.30	17.00	17.55	18.80
1983	19.35	20.00	21.35	21.40	22.35	22.45	23.50	23.60	23.65	23.65	23.85	23.85
1984	23.05	22.50	19.25	17.90	17.00	16.50	16.60	16.40	16.55	16.05	15.90	15.90
1985	16.20	15.70	15.05	14.90	14.45	14.60	14.75	15.10	15.10	15.75	15.80	16.55
1986	16.55	16.70	16.70	17.10	17.15	17.20	17.50	17.45	17.35	17.25	17.30	17.35
1987	17.35	16.90	16.95	17.00	17.20	**17.10**						

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HISTORICAL MARKET DATA

HISTORICAL CONVERSION VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U in UF_6)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	1.20	1.20	1.20	1.40	1.15	1.15	1.15	1.10	1.10	1.10	1.20	1.20
1982	1.20	1.20	1.20	1.20	1.00	1.00	1.00	0.90	1.10	1.60	1.45	1.45
1983	1.20	1.40	1.40	1.20	1.20	1.20	1.10	1.10	1.00	0.60	0.60	0.60
1984	0.60	0.30	0.80	0.80	0.80	0.00	0.00	0.80	1.00	1.00	0.80	0.80
1985	1.00	1.00	1.00	1.50	1.50	1.60	1.60	1.60	1.60	1.60	1.60	1.60
1986	1.60	1.80	1.80	1.90	1.80	1.80	1.80	1.90	1.90	1.90	1.80	1.80
1987	1.80	1.80	1.80	1.80	1.80	**1.80**						

HISTORICAL UF_6 VALUES

Determined as of the last day of the month indicated (US Dollars/kg. U in UF_6)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	—	—	—	40.50	42.50	42.50	44.00	44.50	44.50	46.00	46.00	47.00
1986	47.00	48.00	48.00	48.50	48.25	48.25	48.25	48.00	48.00	48.00	48.00	47.75
1987	47.75	48.00	48.00	48.00	47.75	**47.75**						

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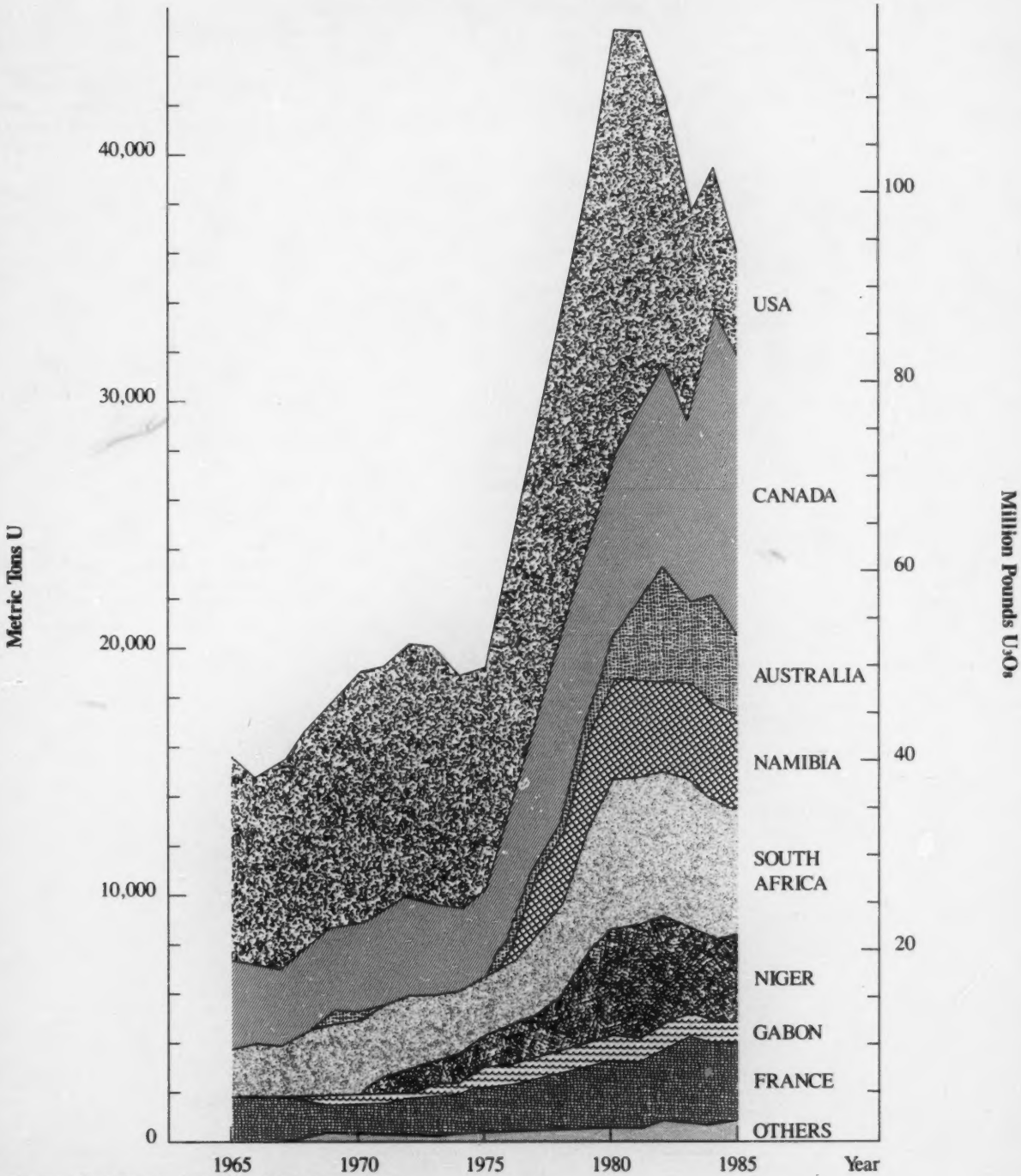
HISTORICAL MARKET DATA

HISTORICAL WOCA[1] URANIUM PRODUCTION[2]
(Compiled by OECD/IAEA Joint Report[3])



[1]WOCA = World Outside of Centrally-planned Economic Areas.

[2]1985 production data are preliminary.

[3]A joint report issued biennially by the OECD Nuclear Energy Agency and the International Atomic Energy Agency.

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HISTORICAL MARKET DATA

US URANIUM MARKETING ACTIVITIES STATISTICS[1]
(Compiled from data published by the US Energy Information Administration)

Year	Total Production[2] (million pounds U_3O_8)	Deliveries to Domestic Utilities[3] (million pounds U_3O_8)	Average Price of Delivered Uranium ($/lb. U_3O_8)	Quantity of Uranium Imported[4] (million pounds U_3O_8)	Average Price of Imported Uranium ($/lb. U_3O_8)	Quantity of Uranium Exported (million pounds U_3O_8)
1976	25.5	n/a	n/a	3.6	n/a	1.2
1977	29.9	n/a	n/a	5.6	n/a	4.0
1978	37.0	n/a	n/a	5.2	n/a	6.8
1979	37.5	33.0[5]	$23.85[5]	3.0	n/a	6.2
1980	43.7	35.0[5]	$28.15[5]	3.6	$43.10	5.8
1981	38.5	32.6[5]	$34.65[5]	6.6	$32.90	4.4
1982	26.9	27.1	$38.37	17.1	$27.23[6]	6.2
1983	21.2	24.2	$38.21	8.2	$26.16	3.3
1984	14.9	22.5	$32.65	12.5	$21.86	2.2
1985	11.3	21.7	$31.43	11.7	$20.08	5.3

[1]Sources: 1979: US Department of Energy, Assistant Secretary for Resource Applications, Office of Uranium Resources and Enrichment, *Survey of United States Uranium Marketing Activity*, DOE/RA-0053 (Washington DC, July 1980). 1980-1981: US Department of Energy, Assistant Secretary for Nuclear Energy, Office of Uranium Enrichment and Assessment, *Survey of United States Uranium Marketing Activity*, DOE/NE-0013 and DOE/NE-0013/1 (Washington DC, June 1981 and July 1982). 1982: Energy Information Administration, *1982 Survey of United States Uranium Marketing Activity*, DOE/EIA-0403 (Washington DC, September 1983). 1983: Energy Information Administration, *Survey of United States Uranium Marketing Activity 1983*, DOE/EIA-0403(83) (Washington DC, August 1984). 1984: Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey" (1984). 1985: Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey" (1985).

[2]Sources: 1976-1982: US Department of Energy, Grand Junction Area Office, *Statistical Data of the Uranium Industry*, GJO-100 (Grand Junction, Colorado, January 1983). 1983: Calculated by the staff of the Nuclear and Alternate Fuels Division, Office of Coal, Nuclear, Electric and Alternate Fuels, Energy Information Administration, from US Department of Energy, Grand Junction Area Office data files. 1984: Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey" (1984). 1985: Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey" (1985).

[3]Excludes direct imports by domestic utilities.

[4]Includes imports by domestic utilities and domestic suppliers.

[5]Includes delivery commitments to domestic utilities and agents.

[6]Computation of quantity-weighted average price excludes the quantity associated with a large exchange (swap) transaction that occurred in 1982.

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VOLUME AND PRICE OF URANIUM DELIVERIES TO THE EUROPEAN COMMUNITY[1]
(Compiled from data published by the Euratom Supply Agency)

Year	Volume of Deliveries to the EC[2] (in MTU)	Percentage of Deliveries Made Under Spot Contracts	Medium or Long-Term Contracts[3,4]		Spot Contracts[3,4]	
			Average Price in ECU per pound U_3O_8	Average Price in US Dollars per pound U_3O_8	Average Price in ECU per pound U_3O_8	Average Price in US Dollars per pound U_3O_8
1977	n/a	n/a	n/a	n/a	n/a	$41.00
1978	n/a	n/a	n/a	n/a	n/a	$43.00
1979	10,000	n/a	n/a	n/a	n/a	$44.50
1980	8,600	n/a	n/a	$36.00	n/a	$35.00
1981	13,000	less than 10	n/a	$33.25	n/a	$28.00
1982	12,500	less than 10	ECU 32.25	$32.00	ECU 24.25	$24.00
1983	13,500	less than 10	ECU 34.75	$31.00	ECU 26.00	$23.25
1984	11,000	less than 10	ECU 37.75	$29.75	ECU 24.50	$19.25
1985	11,000	11.5	ECU 38.00	$29.00	ECU 19.50	$15.00

[1]The twelve European Community member nations are Belgium, Denmark, France, the Federal Republic of Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, and the United Kingdom; prior to January 1986, Spain and Portugal were not members of the EC.

[2]The only deliveries taken into account are those made to final users, namely the electric utilities or their procurement organizations; deliveries to middlemen or fuel cycle companies are not included. The sales between utilities in the Community are also excluded. The quantities covered are those which were entered into accounting records during the year stated.

[3]For deliveries made under medium or long-term contracts (i.e., for which the time between the date of signature and the date of the last delivery exceeds one year) the prices were expressed in seven different currencies. In order to calculate an average price, these prices have been converted into European Currency Units (ECU) and US dollars. The average prices were weighted by quantity and converted on the basis of the average annual exchange rate of the different currencies against the ECU and US dollar.

[4]Exchange rates as published by European Communities Statistical Office and the International Monetary Fund.

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GOVERNMENT STATISTICS

AUSTRALIA

	Consumer Price Index[1]	Price Index of Materials Used in Manufacturing Industry — All Groups[2] (1984 = 100)	Award Rates of Pay Indexes Australia — Adult Males In Mining Wage Earners, Weekly Rates[3] (1976 = 100)
1975 Avg.	57.9	150.4	132.6
1976 Avg.	65.7	168.4	160.9
1977 Avg.	73.8	192.0	179.0
1978 Avg.[4,5]	79.7	198.5	190.0
1979 Avg.	86.9	248.8	127.9
1980 Avg.	95.8	321.8	140.8
1981 Avg.	105.0	355.3	154.1
1982 Avg.[6]	116.7	368.6	174.9
1983 Avg.	128.5	401.6	181.8
FY84 Avg.[7]	133.6	95.3	—
FY85 Avg.[7]	133.6	100.0	—
FY86 Avg.[7]	—	105.0	—
Jan 1986	—	109.6	210.0
Feb 1986	—	108.7	210.0
Mar 1986	150.5	99.5	210.5
Apr 1986	—	94.3	210.5
May 1986	—	93.5	210.5
Jun 1986	153.0	95.7	210.5
Jul 1986	—	98.1	215.3
Aug 1986	—	98.2	215.3
Sep 1986	157.0	105.6	215.3
Oct 1986	—	106.2	215.4
Nov 1986	—	105.2	215.6
Dec 1986	161.5	105.5	215.6
Jan 1987	—	106.4	215.9
Feb 1987	—	109.2	216.5
Mar 1987	164.7	—	217.0

P = Preliminary R = Revised since last month

[1]Weighted average of six State capital cities (1975 to 1980), and eight capital cities from 1981 (Base: year 1980-81 = 100.0). Index periods are for normal calendar years; figures shown at end of year represent yearly average; figures shown at end of quarter represent quarterly average.

[2]Australian Bureau of Statistics, Canberra: "Price Index of Materials Used in Manufacturing Industry" (Catalogue No. 6411.0). The basis of this index was revised to 1984 = 100. The previous index was 1969 = 100.

[3]Australian Bureau of Statistics, Canberra: "Award Rates of Pay Indexes, Australia" (Catalogue No. 6312.0). Figures for the latest fourteen months shown are subject to revision.

[4]Monthly data for 1970-78 appear on pages 4.7 and 4.8 of Report 138.

[5]Annual averages prior to 1979 reflect index base no longer in use.

[6]Monthly data for 1979-82 appear on page 35 of Report 184.

[7]Annual averages are for financial year ending June 30.

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CANADA

	Industry Selling Price Index: All Commodities[1] (1981 = 100)	Wage-earner Data: Average Hourly Earnings (C$)[2]					
		Uranium Mines (SIC 057)	Metal Mines (SIC 051-059)	Mines, Quarries and Oil Wells[3] (SIC 051-099)	Primary Non-ferrous Metal Industries[4] (SIC 296)	(SIC 298)	Chemicals and Chemical Products[5] (SIC 372-379)
1979 Avg.[6]	217.9	—	9.60	9.66	—	—	7.67
1980 Avg.	247.2	—	10.58	10.80	—	—	8.50
1981 Avg.	288.7	—	12.02	12.23	—	—	9.53
1982 Avg.[7]	288.8	—	13.74	13.92	—	—	10.63
1983 Avg.	298.8	—	—	14.30	—	—	11.17
1984 Avg.	310.9	17.88	—	15.07	12.28	10.49	11.76
Jan 1985	117.5	18.05	16.13	15.60	12.32	10.80	12.04
Feb 1985	117.7	18.78	16.41	15.68	12.52	11.05	12.06
Mar 1985	118.4	18.24	16.21	15.57	12.44	10.97	12.02
Apr 1985	118.3	18.63	16.44	15.80	12.81	11.23	12.04
May 1985	118.6	19.41	16.51	15.63	12.76	11.25	12.15
Jun 1985	118.6	18.49	16.20	15.49	12.89	11.14	12.14
Jul 1985	118.6	18.14	16.27	15.41	12.96	11.17	12.13
Aug 1985	118.4	17.07	16.03	15.30	12.97	11.31	12.19
Sep 1985	118.6	18.53	16.55	15.72	12.95	11.39	12.26
Oct 1985	119.0	18.74	16.51	15.70	13.14	11.53	12.33
Nov 1985	119.3	19.05	16.66	15.88	12.76	11.32	12.49
Dec 1985	120.0	19.07	16.57	16.01	12.51	11.09	12.59
Jan 1986	121.0	18.15	16.22	15.86	13.11	11.48	12.52
Feb 1986	120.8	19.52	16.57	15.99	13.20	11.59	12.45
Mar 1986	120.1	19.04	16.65	15.93	13.11	11.59	12.54
Apr 1986	119.3	19.38	16.68	15.95	13.07	11.64	12.54
May 1986	118.4	19.54	16.68	15.78	13.16	11.72	12.51
Jun 1986	118.6	19.80	16.63	15.64	13.44	11.86	12.49
Jul 1986	118.8	19.51	16.34	15.48	13.28	11.73	12.52
Aug 1986	119.1	18.39	16.17	15.46	13.31	11.31	12.70
Sep 1986	119.4	19.32	16.62	15.78	13.14	11.45	12.90
Oct 1986	119.9	19.97	16.81	16.11	13.30	11.59	12.94
Nov 1986	119.9	20.11	17.01	16.24	13.42	11.66	12.93
Dec 1986	119.7	19.67	16.79	16.19	13.06	11.57	12.99
Jan 1987	120.0	19.52	16.84	16.07	13.06	12.56	12.95
Feb 1987	119.8	20.33	17.15	16.09	13.01	12.66	13.18
Mar 1987	120.3	20.04	17.15R	16.02R	13.57R	12.58R	13.09R
Apr 1987	121.1R	20.47P	17.36P	16.21P	13.54P	12.33P	13.28P
May 1987	121.7P	—	—	—	—	—	—

P = Preliminary R = Revised since last month

[1]Statistics Canada, Prices Division, Ottawa: "Industry Price Indexes" (Catalogue 62-011). Indexes for the most recent six months shown are subject to revision. This category was formerly known as "Manufacturing." Index prior to 1985, 1971 = 100.

[2]Statistics Canada, Labour Division, Employment and Payrolls Section, Ottawa: "Employment, Earnings and Hours" (Catalogue 72-002).

[3]Reports 175 :hrough 185 list this series title incorrectly as "Metal Mining, Including Milling (SIC 050-099)."

[4]Beginning with the April 1983 figure, Primary Metal Industries, non-ferrous is split into SIC 296 and SIC 298.

[5]Chemical and Chemical Products prior to April 1983 was SIC 370-379. The new series is from a new survey which includes all companies and is based on a 1970 classification. The old survey only included companies of 20 employees or more.

[6]Monthly ISPI for 1977 and 1978 appear on page 4.10 of Report 138, and monthly wage-earner data for 1973-78 appear on page 4.11 of Report 138.

[7]Monthly data for 1979-1982 appear on page 37 of Report 184. On that page, the wage earner index entitled "Metal Mining, Including Milling (SIC 050-099)" should read "Total Mining (SIC 051-099)."

[8]Beginning with the March 1983 figure, Wage Earner Data are based on a census of all companies employing 200 or more wage earners, *plus* a random survey of companies employing fewer than 200 wage earners. Prior to March 1983 only companies employing 200 or more wage earners are included in the Wage Earner Data.

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GOVERNMENT STATISTICS

REPUBLIC OF SOUTH AFRICA

		Average Declared Working Costs per Metric Ton of Gold Ore Milled (Rand)[1]	Tonnage-Weighted Index of Average Working Costs per Metric Ton of Gold Ore Milled (March 1982 = 100)[2]	Consumer Price Index[3] (1980 = 100)[4]	Producer Price Index All Groups[5] (1980 = 100)	Total Employment in Mining and Quarrying (Code 35)[6]	Total Salaries and Wages in Mining and Quarrying (1,000 Rand) (Code 40)[6]
1975	Avg.	16.71	—	157.2	100.0	639,473	1,003,617
1976	Avg.	19.30	—	174.7	115.1	671,240	1,212,983
1977	Avg.	23.87	—	194.4	130.0	712,006	1,420,670
1978	Avg.	27.14	—	137.2	142.7	664,571	1,537,169
1979	Avg.[7]	30.18	—	155.3	164.5	692,209	1,830,632
1980	Avg.[8]	35.53	—	176.7	192.1	714,379	2,279,615
1981	Avg.	41.89	—	206.5	218.3	728,506	2,820,505
1982	Avg.[9]	47.25	104.2	233.5	248.7	707,552	3,246,071
1983	Avg.	51.87	115.0	262.2	274.8	696,579	3,644,772
1984	Avg.	58.95	130.3	292.8	297.9	712,080	4,196,764
1985	Avg.	68.70	151.68	192.6	181.2	726,804	396,956
Jan	1986	—	—	213.8	203.6	744,070	449,513
Feb	1986	—	—	215.8	206.9	754,458	438,562
Mar	1986	75.76	167.8	218.3	206.9	759,897	445,387
Apr	1986	—	—	222.2	208.9	756,388	437,563
May	1986	—	—	222.6	212.5	754,788	425,544
Jun	1986	77.65	172.0	224.4	213.3	756,637	462,365
Jul	1986	—	—	228.8	216.3	756,140	516,832
Aug	1986	—	—	232.2	220.3	760,929	502,968
Sep	1986	81.94	181.8	236.7	221.9	765,772	511,363
Oct	1986	—	—	239.3	226.8	763,953	512,897
Nov	1986	—	—	242.4	230.2	761,325	531,509
Dec	1986	85.38	189.9	244.9	232.1	752,264	536,970
Jan	1987	—	—	248.3	233.9	740,031	532,577
Feb	1987	—	—	251.0	237.0	741,032	585,461
Mar	1987	88.17	197.1	255.0	239.6	—	—
Apr	1987	—	—	258.2	242.5	—	—
May	1987	—	—	261.2	—	—	—

P = Preliminary R = Revised since last month

[1]Chamber of Mines of South Africa, Johannesburg; "Analysis of Working Results," published quarterly.
[2]Page 16 of Report 178 contains description and calculation of index, and page 24 of Report 178 lists figures for 1982.
[3]Republic of South Africa Department of Statistics, Pretoria; "Government Gazette: Consumer Price Index for Urban Areas."
[4]The basis for calculation prior to January 1985, 1975 = 100. For annual averages prior to 1978, April 1970 = 100.
[5]Previously known as the Wholesale Price Index, now the Producer Price Index. The computation remains the same. The basis for calculation prior to January 1985, 1975 = 100.
[6]Bulletin of Statistics, Department of Statistics, Pretoria.
[7]Historical data for the Average Declared Working Costs and Consumer Price Index 1970-1979 appear on page 4.9 of Report 140.
[8]Monthly data for Codes 35 and 40, 1977-1980, appear on page 28 of Report 157.
[9]Monthly data for 1979-82 appear on page 39 of Report 184.

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UNITED STATES

	Producer Price Index[1]		Consumer Price Index[2] (1967=100)	GNP Implicit Price Deflator[3,4] (1982=100)	Gross Average Hourly Earnings of Production or Non-supervisory Workers (US$)[5]			
	Industrial Commodities (1967=100)	All Commodities (1967=100)			Metal Mining (SIC 10)	Primary Non-ferrous Metals (SIC 333)	Chemicals and Allied Products (SIC 28)	Electric and Electronic Equipment (SIC 36)
1980 Avg.[6]	274.8	268.8	246.8	178.64	10.26	10.63	8.30	6.94
1981 Avg.	304.1	293.4	272.4	195.51	11.55	11.98	9.12	7.62
1982 Avg.[7]	312.3	299.3	289.1	207.15	12.33	12.94	9.96	8.21
1983 Avg.	315.8	303.1	298.4	215.63	12.57	13.43	10.59	8.65
1984 Avg.	322.6	310.3	311.1	108.1	13.05	13.43	11.08	9.04
1985 Avg.	323.9	308.8	322.2	111.7	13.39	13.75	11.56	9.47
Jan 1986	323.8	308.9	328.4	—	13.40	13.69	11.86	9.60
Feb 1986	318.9	304.4	327.5	—	13.44	13.82	11.81	9.60
Mar 1986	314.0	300.3	326.0	113.5	13.38	13.93	11.78	9.62
Apr 1986	311.6	298.2	325.3	—	13.54	13.87	11.82	9.62
May 1986	311.6	299.2	326.3	—	13.46	13.79	11.89	9.64
Jun 1986	311.8	299.0	327.9	114.2	13.52	13.49	11.94	9.61
Jul 1986	308.5	297.4	328.0	—	13.47	13.22	12.04	9.68
Aug 1986	307.9	297.2	328.6	—	13.04	13.18	11.99	9.67
Sep 1986	308.7	297.5	330.2	115.0	13.11	13.41	12.03	9.73
Oct 1986	309.6	298.4	330.5	—	12.51	13.29	12.08	9.72
Nov 1986	309.8	298.7	330.8	—	12.57	13.27	12.15	9.75
Dec 1986	309.3	298.1	331.1	115.3	12.70	13.16	12.20	9.85
Jan 1987	313.6	300.9	333.1	—	12.94R	12.98R	12.18R	9.84R
Feb 1987	315.7	302.7	334.4	—	12.99R	12.83R	12.21R	9.84R
Mar 1987	315.8	302.8	335.9	116.2	13.04R	12.79R	12.24R	9.84R
Apr 1987	317.4	305.1	337.7	—	13.21P	12.91P	12.28P	9.85P
May 1987	318.6	307.3	338.7	—	—	—	12.31P	9.84P

P = Preliminary R = Revised since last month

[1]US Bureau of Labor Statistics, Washington, D.C.: "Producer Prices and Price Indexes," (formerly "Wholesale Prices and Price Indexes"). Producer Price Indexes are revised four months after they are first released to reflect the availability of late reports and corrections by respondents.

[2]US Bureau of Labor Statistics, Washington, D.C.: Consumer Price Index for All Urban Consumers, US City Average, All Items.

[3]US Department of Commerce, Washington, D.C.: Bureau of Economic Analysis, National Income and Wealth Division: "Survey of Current Business." The GNP Implicit Price Deflator is published quarterly, and seasonally adjusted.

[4]The basis for calculation of this index was revised to 1982 = 100. 1984 and 1985 figures have been adjusted to that basis. The basis for calculation prior to 1984, 1972 = 100.

[5]US Bureau of Labor Statistics, Washington, D.C.: "Employment and Earnings." All data based on 1972 revision of SIC Manual. Data for 1970-1976 are adjusted to the March 1977 benchmark. Data for 1977-1978 are adjusted to the March 1979 benchmark. Data for January 1979 to April 1985 are adjusted to the March 1980 benchmark. Data for January 1986 and beyond are adjusted to the March 1986 benchmark.

[6]Monthly data 1970-1978 for Producer Price Index-Industrial Commodities, Consumer Price Index, and Employment and Earnings SIC codes 10, 333, and 28, and quarterly data for GNP Implicit Price Deflator appear on pages 4.6-4.8 of Report 139.
Monthly data 1977-1978 for Employment and Earnings SIC Codes 10, 333, and 28 appear on page 33 of Report 147.
Monthly data 1970-1978 for Employment and Earnings SIC Code 36 appear on page 23 of Report 154.
Monthly data 1977-1980 for Producer Price Index-All Commodities, appear on page 21 of Nuexco Report 158.

[7]Monthly data 1979-1982 for all listed indices appear on page 41 of Report 184.

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